

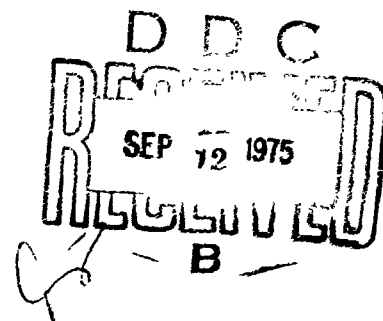
SUPERCritical FLOW AT OPEN-CHANNEL JUNCTIONS

Hydraulic Model Investigation



Report No. 2-100

July 1975



U. S. Army Engineer District, Los Angeles
CORPS OF ENGINEERS
Los Angeles, California

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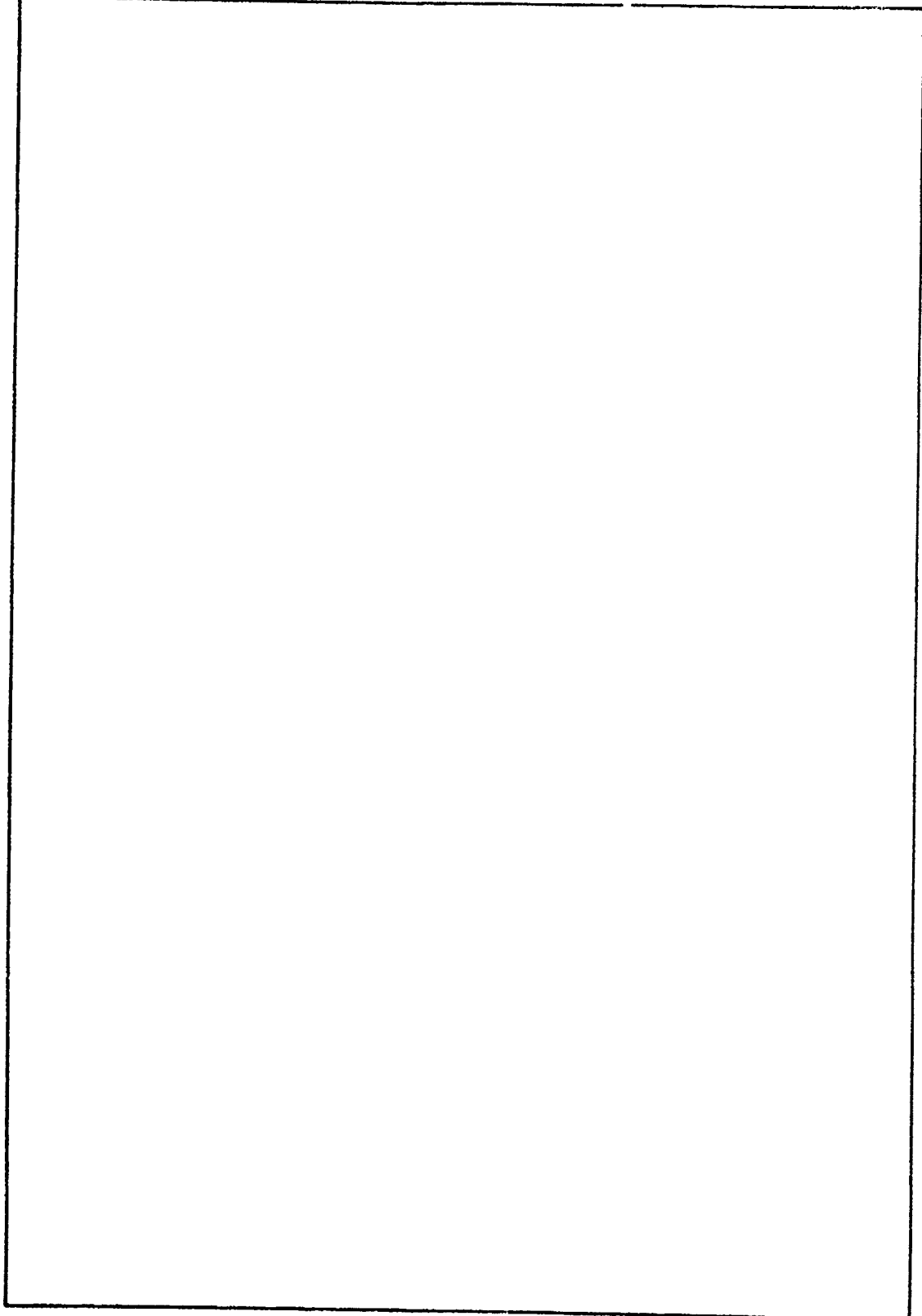
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FOREWORD

The hydraulic studies reported herein were conducted in the Hydraulic Laboratory of the U. S. Army Engineer District, Los Angeles. Preparation and publication of the report were authorized by the Office, Chief of Engineers, in a letter dated 21 August 1969 to the Director, U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss.

This report was prepared by Mr. D. A. Barela, Hydraulics Section, Los Angeles District, under the supervision of Mr. A. Robles, Jr., Chief of the Hydrologic and Hydraulics Branch. COL John V. Foley was District Engineer during publication of the report.

The report was reviewed and published by WES. COL G. H. Hilt was Director of WES during publication of the report; Mr. F. R. Brown was Technical Director.

CONTENTS

	<u>Page</u>
FOREWORD	iii
CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI)	
UNITS OF MEASUREMENT	ix
LIST OF ABBREVIATIONS	x
SUMMARY	xi
INTRODUCTION	1
PURPOSE OF STUDY	1
THE MODELS	2
Description	2
Scale Relations	2
Model Adjustment	2
TABLE 1	
BIG DALTON WASH-EAST BRANCH INLET	5
The Prototype	5
The Model	6
Original Design	6
Final Design	7
PHOTOS 1-9	
PLATES 1-4	
BIG DALTON WASH-LITTLE DALTON WASH	25
The Prototype	25
The Model	25
Original Design	25
Final Design	26
PHOTOS 10-15	
PLATES 5-10	
UPPER SAWTELLE-WESTWOOD SYSTEM, SAWTELLE BRANCH-WESTWOOD BRANCH	39
The Prototype	39
The Model	39
PHOTOS 16-21	
PLATES 11-13	
UPPER SAWTELLE-WESTWOOD SYSTEM, WESTWOOD BRANCH CHANNEL-WILSHIRE SIDE DRAINS	51
The Prototype	51
Original Design	51

CONTENTS

	<u>Page</u>
Alternative Design	52
Final Design	52
PHOTOS 22-27	
PLATES 14-17	
UPPER BURBANK-WESTERN SYSTEM, BURBANK-WESTERN CHANNEL - STOUGH CANYON	69
The Prototype	69
Original Design	70
Alternative and Final Designs	70
PHOTOS 28-33	
PLATES 18-21	
UPPER BURBANK-WESTERN SYSTEM, BURBANK-WESTERN CHANNEL - HANSEN HEIGHTS CHANNEL	82
The Prototype	82
Original-Final Design	82
PHOTOS 34-37	
PLATES 22 and 23	
BALLONA CREEK CHANNEL-BENEDICT CANYON CHANNEL	93
The Prototype	93
The Model	93
Original-Final Design	94
PHOTOS 38-40	
PLATES 24 and 25	
BENEDICT CANYON CHANNEL - REXFORD-MONTE MAR CHANNEL	103
The Model	103
Final Design	103
PHOTOS 41-43	
PLATES 26-29	
SAN ANTONIO CHANNEL-CHINO CREEK CHANNEL	115
Original Design	115
Alternative Design	115
Final Design	116
PHOTOS 44-49	
PLATES 30-34	
PACOIMA WASH CHANNEL-WILSON MANSFIELD CHANNEL	135

CONTENTS

	<u>Page</u>
The Model	135
Final Design	135
PHOTOS 50-52	
PLATES 35 and 36	
TUJUNGA WASH CHANNEL-PACOIMA WASH CHANNEL	145
The Model	145
Final Design	145
PHOTOS 53-55	
PLATES 37-42	
CONCLUSIONS	161

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI)
UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
inches	2.54	centimeters
feet	0.3048	meters
miles (U. S. statute)	1.609344	kilometers
feet per second	0.3048	meters per second
cubic feet per second	0.02831685	cubic meters per second

LIST OF ABBREVIATIONS

S. T.	Point of change from spiral to tangent
T. S.	Point of change from tangent to spiral
C. S.	Point of change from circular curve to spiral
S. C.	Point of change from spiral to circular curve
T. C.	Point of change from tangent to circular curve
C. T.	Point of change from circular curve to tangent
B. C.	Beginning of confluence
E. C.	End of confluence

SUMMARY

This report describes hydraulic model tests made to generalize and verify the hydraulic design of confluence structures. Model investigation of certain confluences showed unsatisfactory flow conditions involving considerable turbulence in the confluence structure and transverse waves in the channel downstream. Major changes in particular designs were effected. Various schemes were introduced in each case. Lengthening the transition downstream from divider wall and minimal angle of intersection of the two channels were found to be the most efficient solutions.

SUPERCritical FLOW AT OPEN-CHANNEL JUNCTIONS

Hydraulic Model Investigation

INTRODUCTION

1. One of the most important hydraulic problems in the design of flood-control channels is the analysis of the flow conditions at open-channel junctions. Relatively little discussion on method of analysis can be found in standard textbooks on hydraulics. The Los Angeles District (LAD) has developed equations, based on the momentum principle, for the analysis of several types of open-channel junctions commonly used in flood-control channel systems when flow is supercritical.

2. The drainage for the Los Angeles basin is provided by several main channels; each of these main channels is fed by many branches and washes from mountain and ridge slopes. The design of the junctions for these tributaries became an important hydraulic problem in so far as the functional adequacy and overall project cost were concerned. Because of many variables, such as the angle of intersection, shape and size of channels, rate and type of flow, each junction had to be treated differently to accommodate local conditions. Flow characteristics for these major junctions were analyzed by the momentum equations and verified by model tests.

3. Eleven individual model studies are submitted in this report; each model had a scale ratio of either 1:20, 1:24, 1:25, 1:30, or 1:40. The material comprising this report is drawn from accepted theory, tests, and observations.

PURPOSE OF STUDY

4. The hydraulic models described in this report were studied for the purpose of determining: (a) the flow conditions and impact existing in the channels in the vicinity of the junction, (b) the backwater

effect, if any, in the two channels, and (c) the wave pattern set up in the channel downstream of the junction.

THE MODELS

Description

5. Eleven models were constructed of timber and plywood to simulate the proposed junctions; various undistorted scale ratios were used as given in Table 1. The joists that supported the deck were attached to stringers by means of adjustable bolts; this enabled the slope to be varied as needed.

6. Water used in the operation of the models was supplied by centrifugal pumps operating in a circulating system. The measuring devices used to determine the inflow into the models consisted of both weirs and venturi meters. After passing through the model, the water returned to the sump by gravity flow. Wooden rails set to grade along each side of the model channels provided a datum plane for use of measuring devices. Water-surface elevations were measured with a point gage and velocities were measured with a Prandtl tube.

Scale Relations

7. The similitude relations between the model and the prototype are based on the Froude law which assumes gravity as the dominant force. The resulting mathematical relations between the basic hydraulic quantities of the model and the prototype are summarized in Table 1. Unless otherwise designated, the quantities given in this report refer to the prototype.

Model Adjustment

8. The assumed design roughness (Manning's n) of the prototype concrete junctions was 0.014. The painted plywood surface of the models

was determined to have a coefficient of roughness equal to 0.0088 which is equivalent to values greater than 0.014 in prototype scales; therefore, supplementary slope was added so that the computed depths and velocities of the prototype were reproduced in the model.

Table 1

Scale Relations

Dimension	Confluences	
	Ratio	
Length	L_r	1:20
	$A_r = L_r^2$	1:400
	$Q_r = L_r^{5/2}$	1:1789
	$V_r = L_r^{1/2}$	1:4.47
	$N_r = L_r^{1/6}$	1:1.648
Area	L_r	1:24
	$A_r = L_r^2$	1:576
	$Q_r = L_r^{5/2}$	1:2822
	$V_r = L_r^{1/2}$	1:4.9
	$N_r = L_r^{1/6}$	1:1.698
Discharge	L_r	1:30
	$A_r = L_r^2$	1:900
	$Q_r = L_r^{5/2}$	1:4930
	$V_r = L_r^{1/2}$	1:5.48
	$N_r = L_r^{1/6}$	1:1.763
Velocity	L_r	1:40
	$A_r = L_r^2$	1:1600
	$Q_r = L_r^{5/2}$	1:10119
	$V_r = L_r^{1/2}$	1:6.33
	$N_r = L_r^{1/6}$	1:1.849
Roughness	L_r	1:30
	$A_r = L_r^2$	1:900
	$Q_r = L_r^{5/2}$	1:4930
	$V_r = L_r^{1/2}$	1:5.48
	$N_r = L_r^{1/6}$	1:1.763

BIG DALTON WASH-EAST BRANCH INLET

The Prototype

9. The confluence of Big Dalton Wash-East Branch Inlet, part of the Big Dalton Wash channel improvement, is located near the southeast boundary of the city of Glendora about 23 miles* east of Los Angeles, Calif. Big Dalton Wash is herein designated as the main channel, and East Branch Inlet enters the main channel.

10. Big Dalton Wash is a rectangular concrete-lined section with an "n" value of 0.014. The channel upstream from the confluence has a base width of 20 ft. The base width of the channel at the end of the divider wall is 38 ft; 80 ft downstream the base width of the confluence structure narrows to 30 ft. The main channel upstream of the confluence will carry a discharge of 7000 cfs at a depth and velocity of 8.0 ft and 44 fps, respectively. At the junction, the combined discharge is 10,400 cfs; the additional 3400 cfs enters the main channel from the East Branch Inlet. Downstream from the confluence, the depth and velocity are 9.0 ft and 39 fps, respectively.

11. East Branch Inlet is a rectangular concrete-lined section with an "n" value of 0.014. The inlet channel is designed for a discharge of 3400 cfs. The depth and velocity at the upstream end are 10.0 ft and 20 fps, respectively. Near the junction, the depth decreases to 7.0 ft and the velocity increases to 30 fps. The inlet channel is 17.0 ft wide and the alignment of the channel is such that the direction of flow in the channel would be parallel with the flow in the main channel at the junction of the two channels. The existing channel upstream from the improved inlet is a well-defined natural channel, trapezoidal in cross section. A constant side-slope transition conveys the flow from the trapezoidal section to the rectangular section. The velocity of flow will be subcritical through the transition and will become supercritical at the end of the transition.

* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page ix.

The Model

12. The model, constructed to an undistorted scale ratio of 1:20, simulated 440 ft of main channel upstream from the confluence, the East Branch Inlet channel, and 1240 ft of main channel downstream from the confluence. The trapezoidal channel portion of the East Branch channel upstream from the transition was simulated by cementing small gravel particles to the plywood deck and side slopes.

Original Design

13. The original design was constructed as shown in Plate 1 and Photo 1. The end of the divider wall was located at S.T. sta 466+36.51. Upstream from the confluence, Big Dalton Wash and East Branch Inlet have a width of 20 and 17 ft, respectively. The channel downstream from the end of the divider wall to T.S. sta 463+81.14 was 38 ft wide and narrowed to 30 ft wide at sta 463+00; the 30-ft-wide channel extended downstream to sta 460+00.

14. The original design was planned to combine the supercritical flows of Big Dalton and East Branch in a common channel and convey the design flows of 7000 and 3400 cfs, respectively, through the entire reach with minimum disturbance. Flow conditions around the superelevated curves of both channels upstream from the confluence were satisfactory. The confluence functioned satisfactorily for the combined discharge of 10,400 cfs (Photo 2). The water-surface differential between the two flows at the end of the divider wall was 1.25 ft. Water-surface profiles measured for the design discharge compared favorably with the computed flow; however, flow conditions in the channel downstream from the junction were unsatisfactory. The change in the alignment of the main channel immediately downstream from the divider wall and the transition that followed the 38-ft-wide channel caused waves that extended downstream. Velocity measurements at the junction indicated that the flow entering the main channel moved at an even distribution but was aggravated by the curve immediately downstream from the

divider wall. The combination of these factors produced a slightly unsatisfactory flow condition in the downstream reach (Photo 2).

15. Two other combinations of discharge were introduced into the model: (a) 7000 cfs in Big Dalton Wash with no flow in East Branch Inlet, and (b) 3400 cfs in East Branch Inlet with no flow in Big Dalton Wash. Flow conditions were observed throughout the entire reach, with particular attention being given to the flow at the junction and the transition downstream. Photo 3 shows the general flow conditions for these two flow combinations. The water-surface profiles and the velocity distribution cross sections for the design discharge are shown in Plates 1 and 2, respectively.

Final Design

16. For this design, the model was entirely reconstructed from the divider wall downstream and lengthened to include a second curve downstream. The transition was moved from its original location to a location immediately downstream of the divider wall and the channel alignment changed downstream. Since the flow distribution in the main channel and East Branch was satisfactory in the original design, no changes were made to either channel upstream from the junction. Plate 3 and Photo 4 show the final channel alignment. All efforts during this investigation were directed toward obtaining a more uniform distribution of flow through the confluence and in the main channel downstream. An access ramp was incorporated in this design. The ramp, located at sta 463+20, was 15 ft wide and normal to the centerline of the channel (Photo 5).

17. The final design was tested for the design discharge of 10,400 cfs. Model tests indicated that the design of the confluence was satisfactory. Flow conditions at and downstream from the junction are shown in Photo 6. Realignment of the channel improved flow conditions although the waves were not completely eliminated. Waves downstream from the confluence were smaller than those in the original design. Disturbance developed in the channel downstream from the curves

and transverse waves were observed; however, these were not considered objectionable as they diminished rapidly and ample wall height was provided. The ramp did not produce any undesirable disturbance (Photo 7). The ramp, as designed, proved to be satisfactory. Water-surface profiles for the design discharge are shown in Plate 3 and velocity distribution cross sections are shown in Plate 4.

18. Two other combinations of discharge were introduced into the model and flow conditions were observed throughout the entire reach. These combinations were less effective in reducing the disturbance. One of the combinations tested was 8000 cfs in Big Dalton Wash and 2000 cfs in East Branch channel. This combination caused considerable turbulence in the reach below the transition. The other combination was 7000 and 1000 cfs flowing in Big Dalton and East Branch, respectively. Flow conditions for these combinations are shown in Photos 8 and 9. No further studies were made with this design.



Looking downstream



Looking downstream from East Branch channel



General view, looking upstream



Looking upstream, closeup of confluence

Photo 1. Original design, Big Dalton Wash-East Branch Inlet



Looking downstream

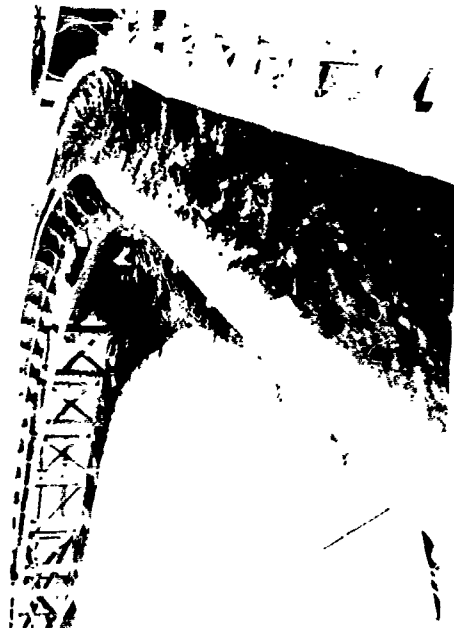


Photo 2. Looking upstream, combined discharge 10,400 cfs
Original design flow conditions; Big Dalton 7000 cfs, East Branch 3400 cfs

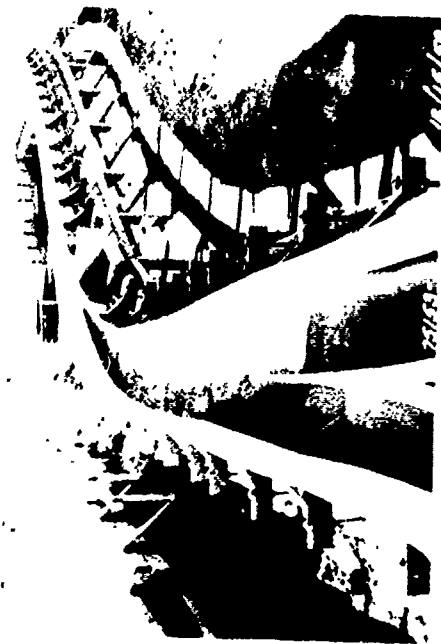


Big Dalton 7000 cfs, East Branch 0 cfs



Big Dalton 0 cfs, East Branch 3400 cfs

Photo 3. Original design flow conditions, looking downstream



Looking downstream



Looking upstream

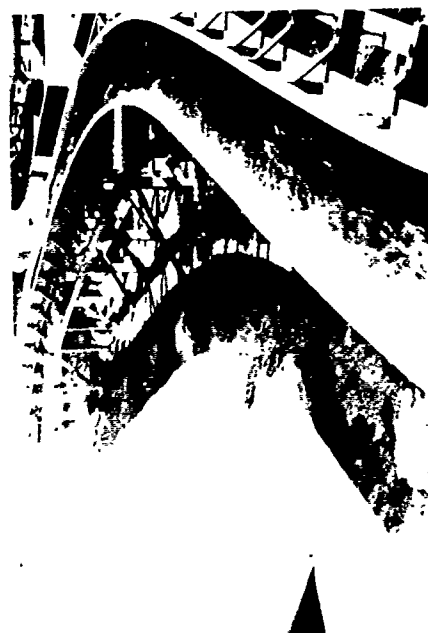
Photo 4. Final design, Big Dalton Wash-East Branch Inlet



Photo 5. Final design, access ramp at sta 463+20



Looking downstream



Looking upstream, combined flow 10,400 cfs

Photo 6. Final design flow conditions; Big Dalton 7000 cfs, East Branch 3400 cfs



Discharge 10,400 cfs



Discharge 8000 cfs

Photo 7. Final design, flow past access ramp



Looking downstream



Looking upstream, combined flow 8000 cfs
Big Dalton 7000 cfs, East Branch 1000 cfs

Photo 8.

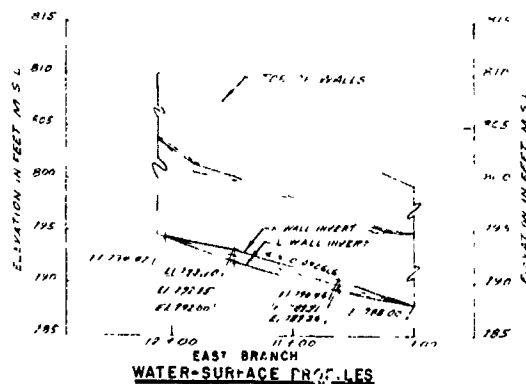
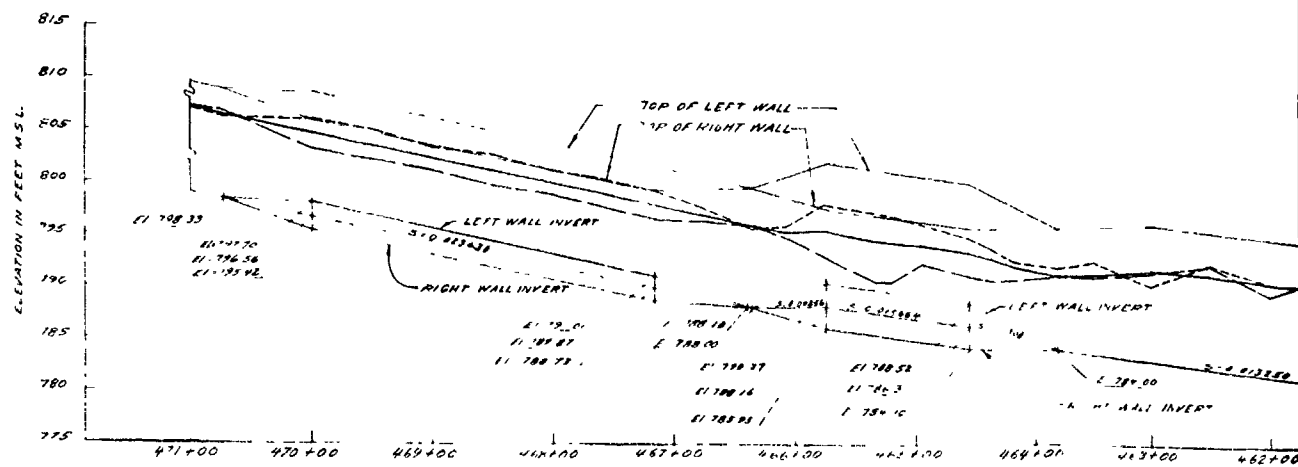
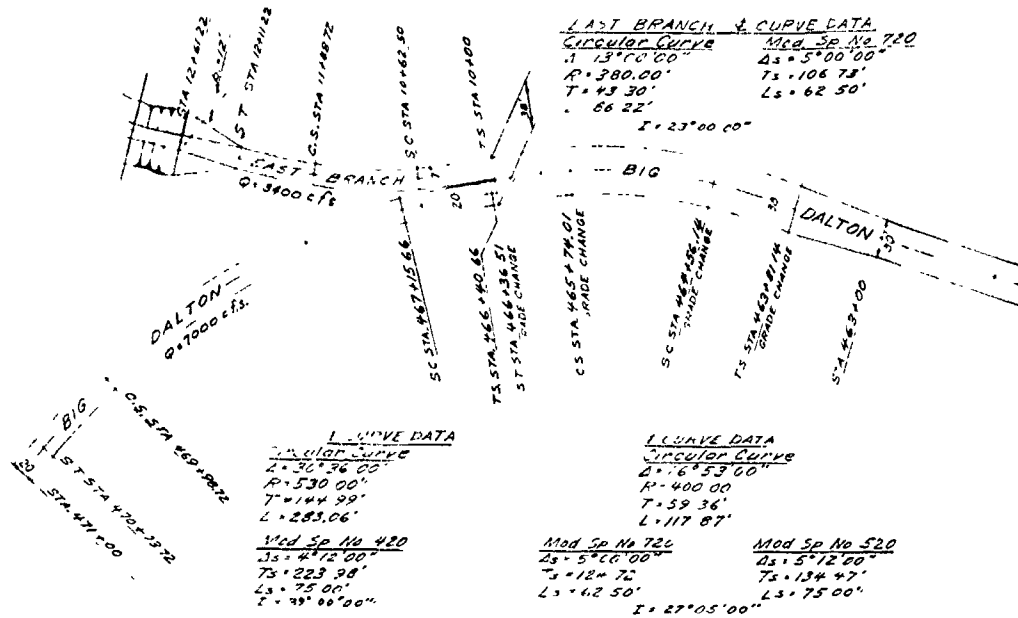


Looking downstream



Looking upstream, combined flow 10,000 cfs

Photo 9. Final design flow conditions; Big Dalton 8000 cfs, East Branch 2000 cfs

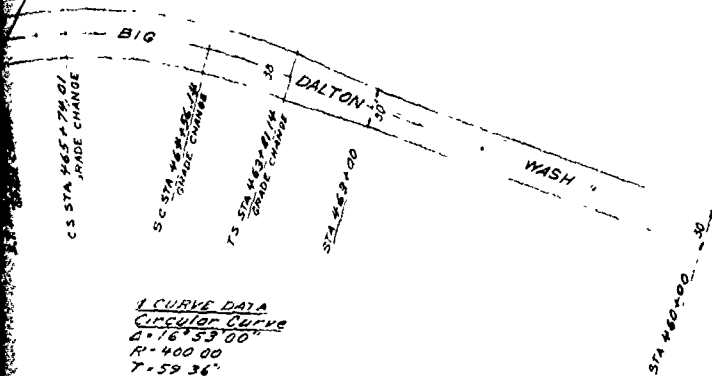


LEGEND

- LEFT WALL WATER SURFACE
- RIGHT WALL WATER SURFACE
- AVERAGE WATER SURFACE

EAST BRANCH & CURVE DATA
CIRCULAR CURVE MOD. SP. NO. 720
 $\Delta = 15^{\circ}00'00''$ $\Delta S = 5^{\circ}00'00''$
 $R = 380.00'$ $Ts = 106.78'$
 $T = 43.30'$ $Ls = 62.50'$
 $L = 66.22'$

$I = 23^{\circ}00'00''$

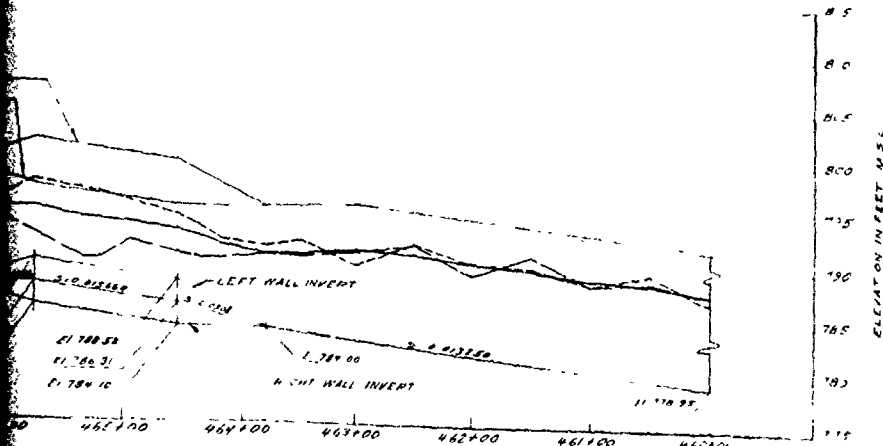


1 CURVE DATA
CIRCULAR CURVE
 $\Delta = 16^{\circ}53'00''$
 $R = 400.00'$
 $T = 59.36'$
 $L = 117.67'$

Mod. Sp. No. 720 Mod. Sp. No. 520
 $\Delta S = 5^{\circ}00'00''$ $\Delta S = 5^{\circ}12'00''$
 $Ts = 124.72'$ $Ts = 134.47'$
 $Ls = 62.50'$ $Ls = 75.00'$
 $I = 27^{\circ}05'00''$

PLAN

SCALE IN FEET
 0 100 200



LONG CENTERLINE
DALTON
WASH
WATER SURFACES

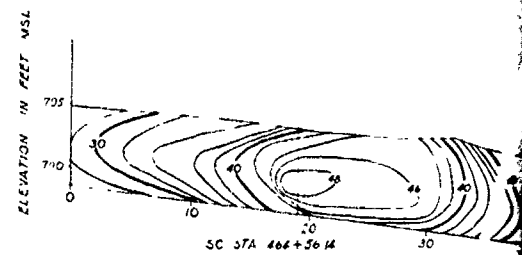
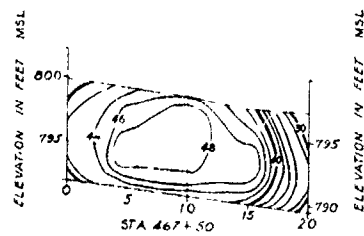
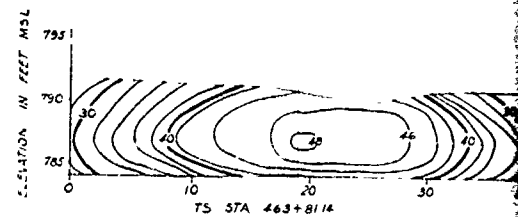
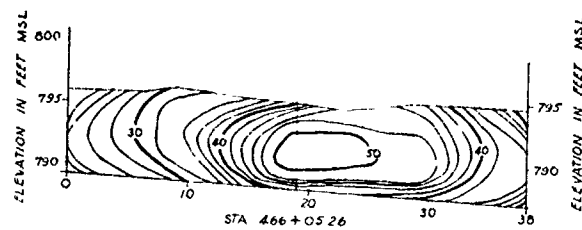
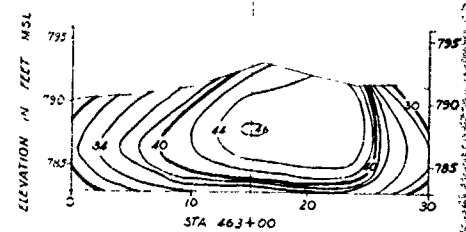
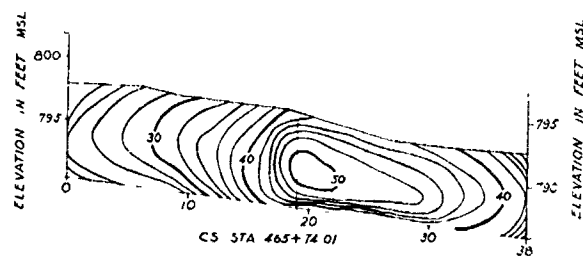
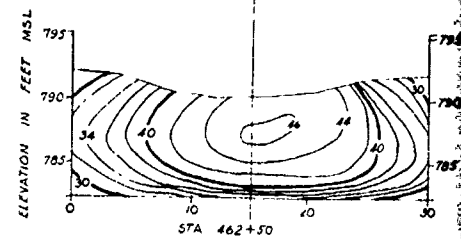
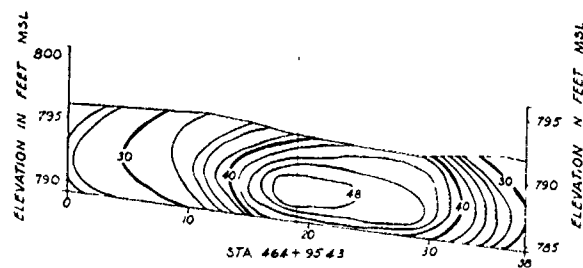
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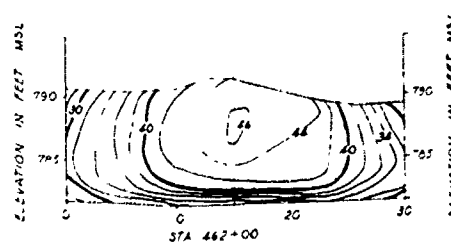
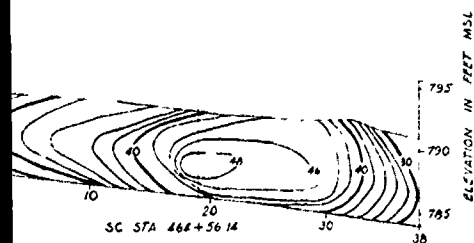
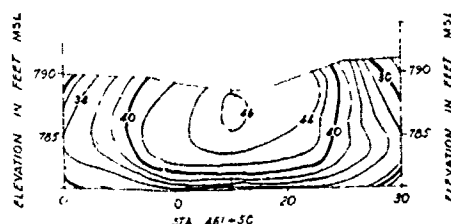
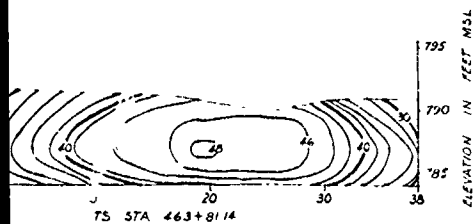
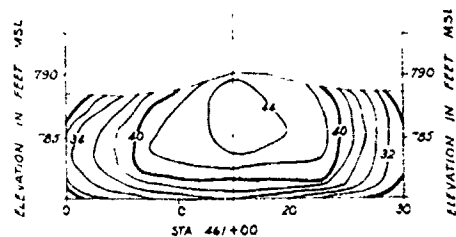
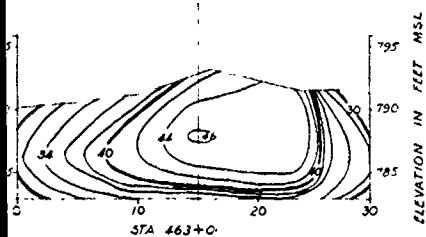
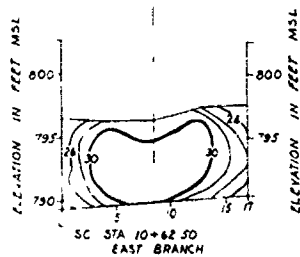
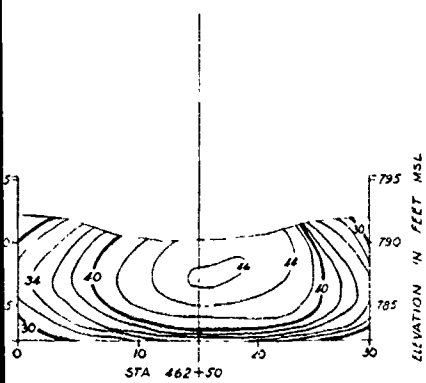
--- LEFT WALL WATER SURFACE
 --- RIGHT WALL WATER SURFACE
 --- AVERAGE WATER SURFACE

MODEL LAYOUT
 AND
 WATER-SURFACE PROFILES
 ORIGINAL DESIGN
 TOTAL DISCHARGE 10,400cfs

PLATE 1

2

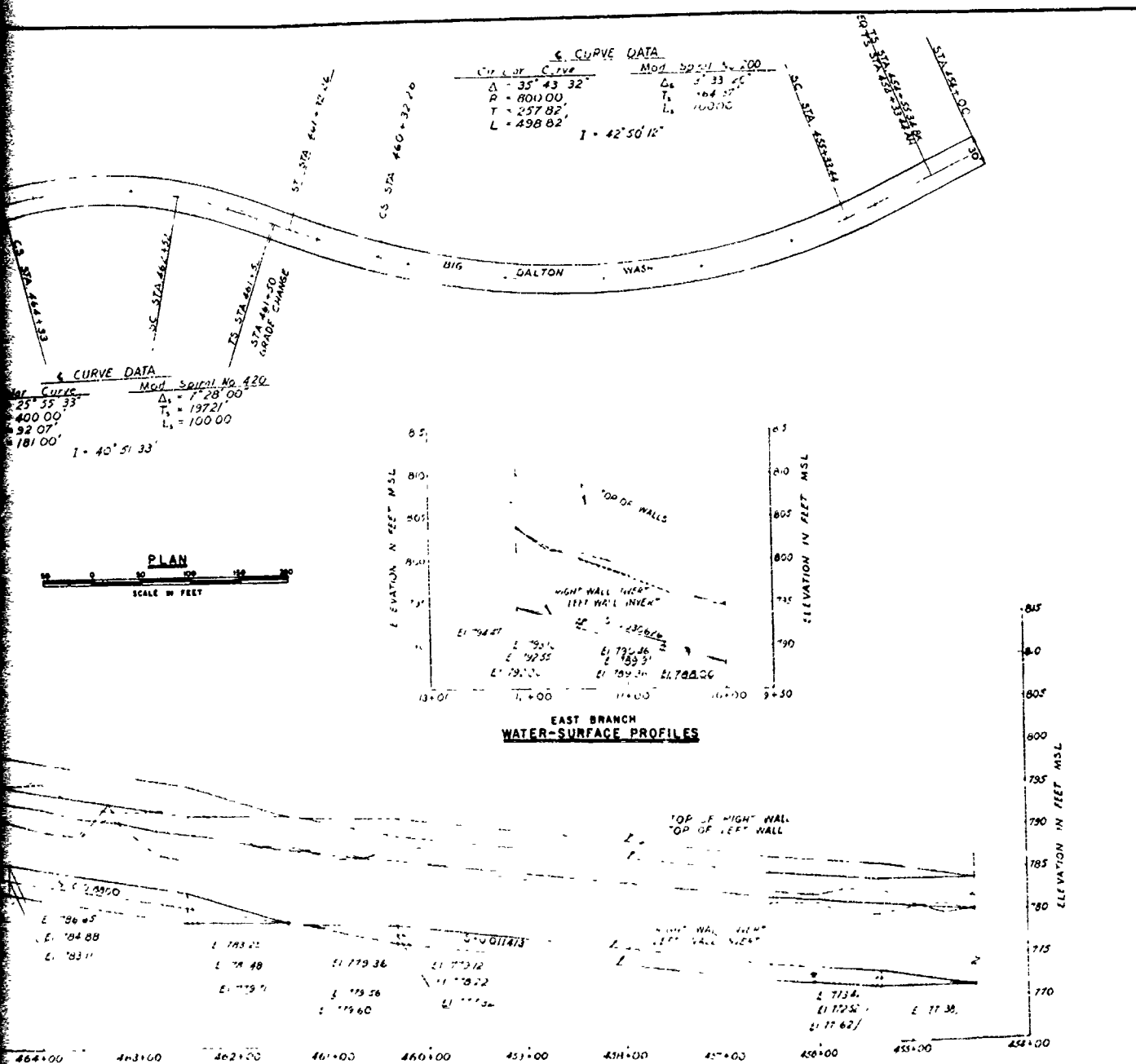




NOTE:

Sections are shown looking downstream
Velocity contour interval is two feet
Discharge upstream of confluence:
Big Dalton Wash Channel=7,000 cfs
East Branch=3,400 cfs
Discharge downstream of confluence:
Big Dalton Wash Channel=10,400 cfs
Coefficient of friction=0.014

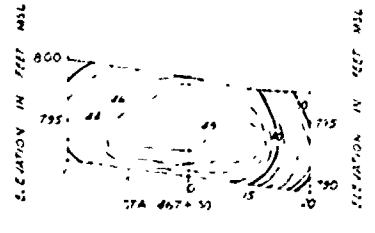
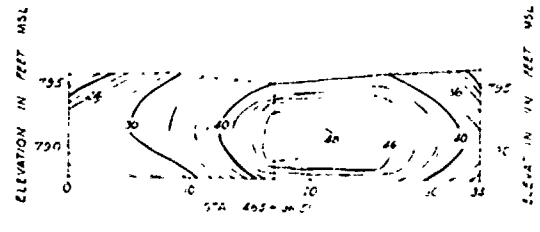
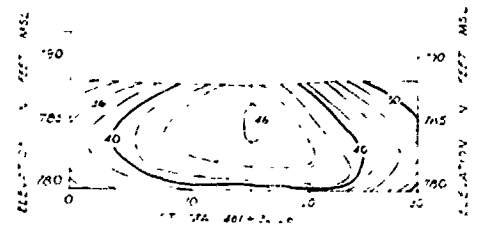
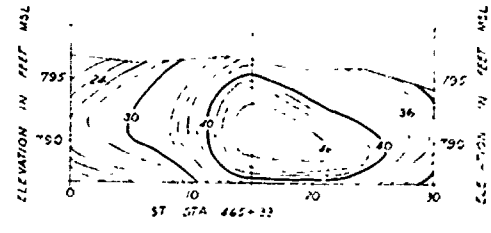
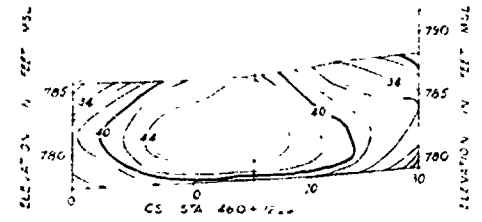
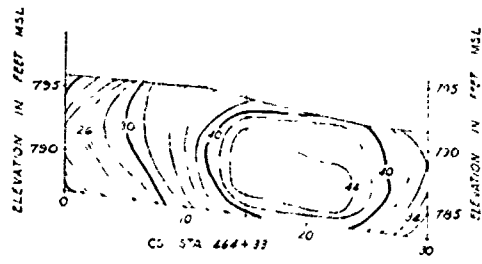
**VELOCITY DISTRIBUTION
ORIGINAL DESIGN
TOTAL DISCHARGE 10,400cfs**

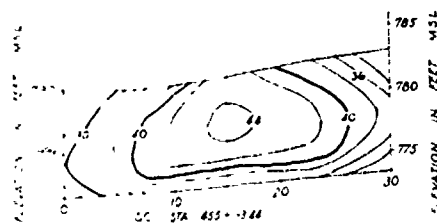
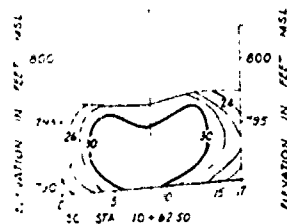
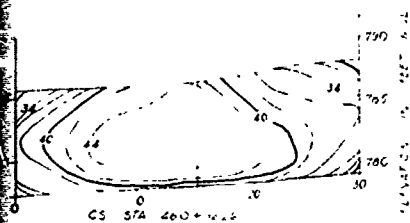


STATIONS ALONG CENTERLINE
BIG DALTON
WATER-SURFACE PROFILES

LEGEND
 - - - - - LEFT WALL WATER SURFACE
 ——— RIGHT WALL WATER SURFACE
 AVERAGE WATER SURFACE

**MODEL LAYOUT
AND
WATER-SURFACE PROFILES
FINAL DESIGN**
 TOTAL DISCHARGE 10,400cfs





NOTE

Sections are shown looking downstream
 Velocity contour interval = 1.0 ft/s
 Discharge upstream of confluence
 Big Darfur Wash Channel = 1000 cfs
 East Branch = 400 cfs
 Discharge downstream of confluence
 Big Darfur Wash Channel = 10400 cfs
 Coefficient of friction = 0.018

**VELOCITY DISTRIBUTION
 FINAL DESIGN
 TOTAL DISCHARGE 10,400cfs**

BIG DALTON WASH-LITTLE DALTON WASH

The Prototype

19. The Big Dalton Wash-Little Dalton Wash confluence is located about 17 miles east of the city of Los Angeles in an unincorporated area of Los Angeles County near the city of Baldwin Park. The confluence is part of the Big Dalton Wash channel improvement. The Big Dalton Wash channel, which is part of the Walnut Creek system, is an open rectangular channel; the base width ranges from 40 to 60 ft. The Little Dalton Wash channel is also rectangular in cross section and has a base width of 30 ft. The channels converge at an angle of approximately 7 degrees with the invert elevations being the same at the end of the divider wall. Both channels are on about a 1 percent slope.

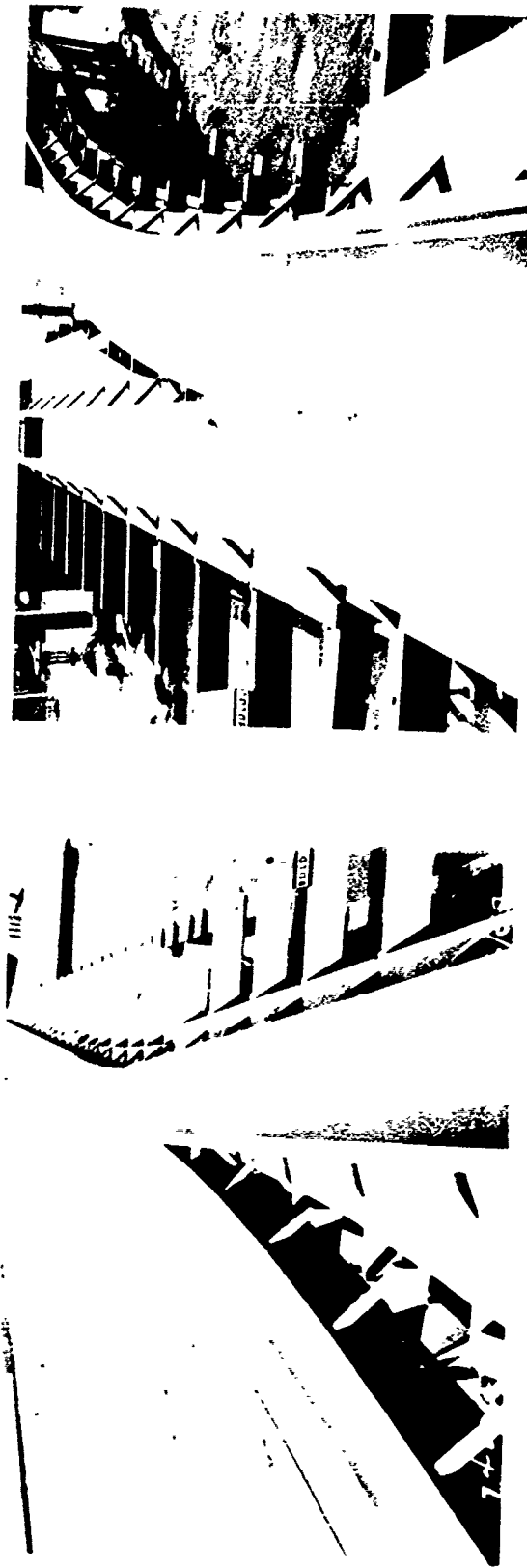
The Model

20. The model, constructed to an undistorted scale ratio of 1:30, reproduced 650 ft of Little Dalton Wash channel and 2000 ft of Big Dalton Wash of which 1300 ft was downstream from the confluence.

Original Design

21. Upstream from the junction, Big Dalton Wash and Little Dalton Wash have a base width of 40 and 30 ft, respectively. The combined width of the two channels becomes 71 ft at the end of the divider wall. At the downstream end of the confluence, sta 184+85.74, the channel transitioned to a width of 60 ft (Photo 10).

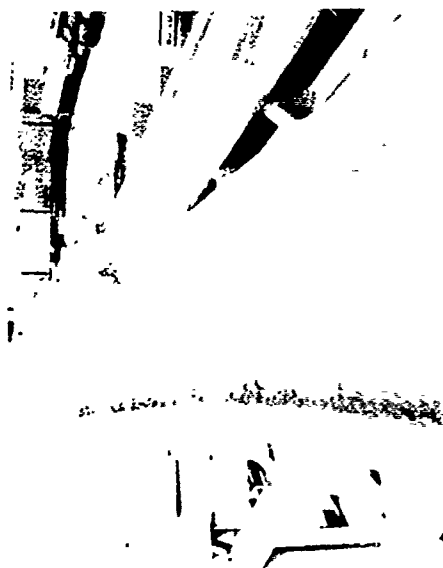
22. Two combinations of flow were considered pertinent to the design of the confluence. One combination was for a discharge of 16,000 cfs in Big Dalton Wash and 9,500 cfs in Little Dalton Wash. With this flow combination, the difference in water-surface elevation between the two channels at the end of the divider wall was 1.8 ft. This differential resulted in the formation of standing waves in the confluence



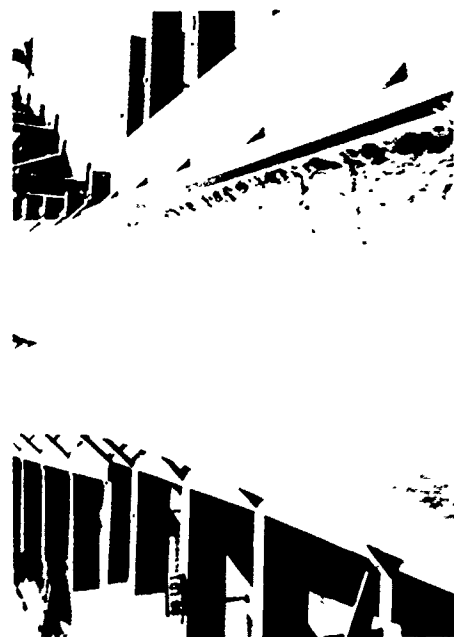
Looking downstream from Little Dalton Wash

Looking upstream from sta 183+50, Big Dalton Wash

Photo 10. Original design, Big Dalton Wash-Little Dalton Wash

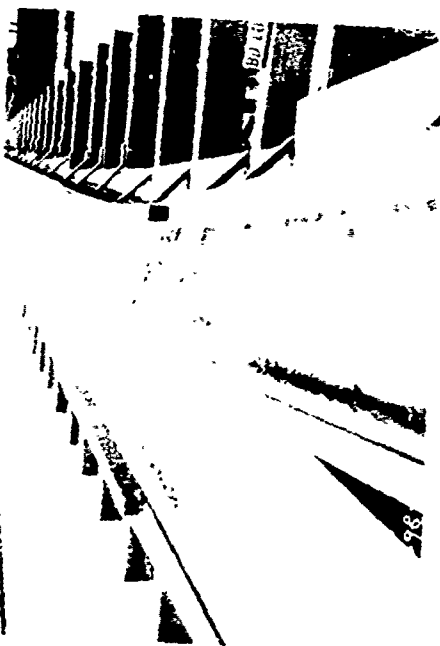


Looking downstream



Looking upstream, combined flow 25,500 cfs

Photo 11. Original design flow conditions; Big Dalton Wash 16,000 cfs, Little Dalton Wash 9,500 cfs



Looking downstream from Little Dalton Wash



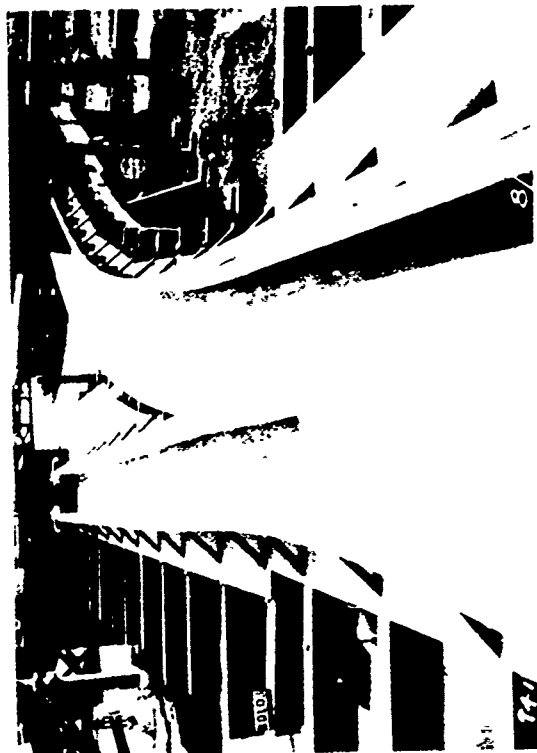
Looking downstream from Big Dalton Wash



Looking upstream from sta 183+50, Big Dalton Wash, combined flow 25,500 cfs
Photo 12. Original design flow conditions; Big Dalton Wash 18,500 cfs, Little Dalton Wash 7,000 cfs



Looking downstream from Little Dalton Wash



Looking upstream from sta 183+50, Big Dalton Wash

Photo 13. Final design, Big Dalton Wash-Little Dalton Wash



Looking downstream from Little Dalton Wash

Photo 14. Final design flow conditions; Big Dalton Wash 16,000 cfs, Little Dalton Wash 9,500 cfs



Looking upstream from sta 183+50, Big Dalton Wash
Combined flow 25,500 cfs

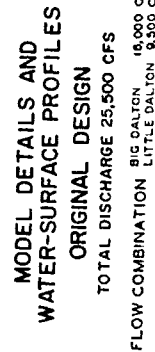


Looking downstream from Big Dalton Wash



Looking upstream from sta 181+00, Big Dalton Wash
Combined flow 25,500 cfs

Photo 15. Final design flow conditions; Big Dalton Wash 18,500 cfs, Little Dalton Wash 7,000 cfs



NOTE: ASTERISK(*) ON PLAN
INDICATES LISTED DALTON DATA

THE JOURNAL OF THE
WASHINGTON CHANNEL

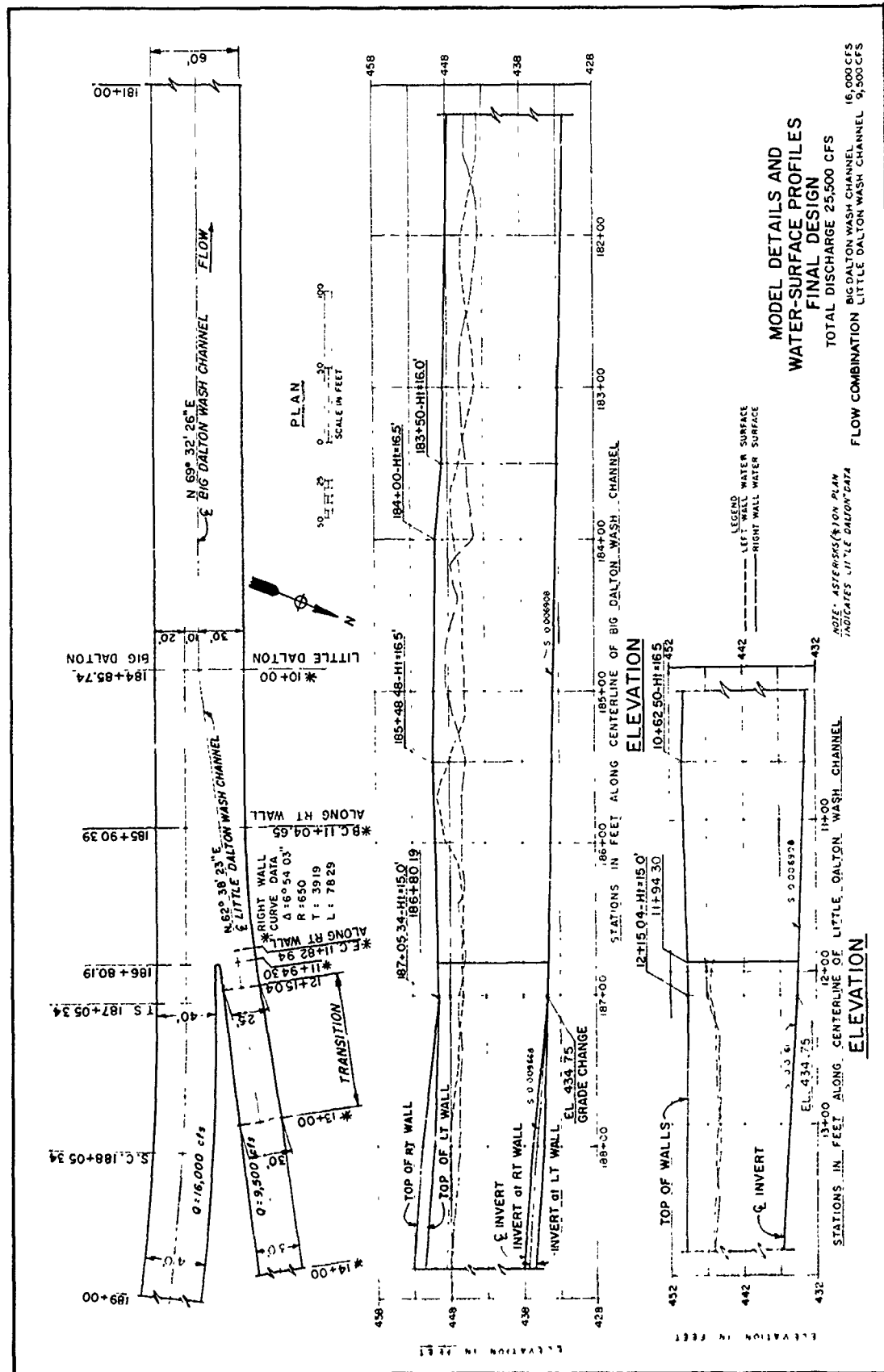
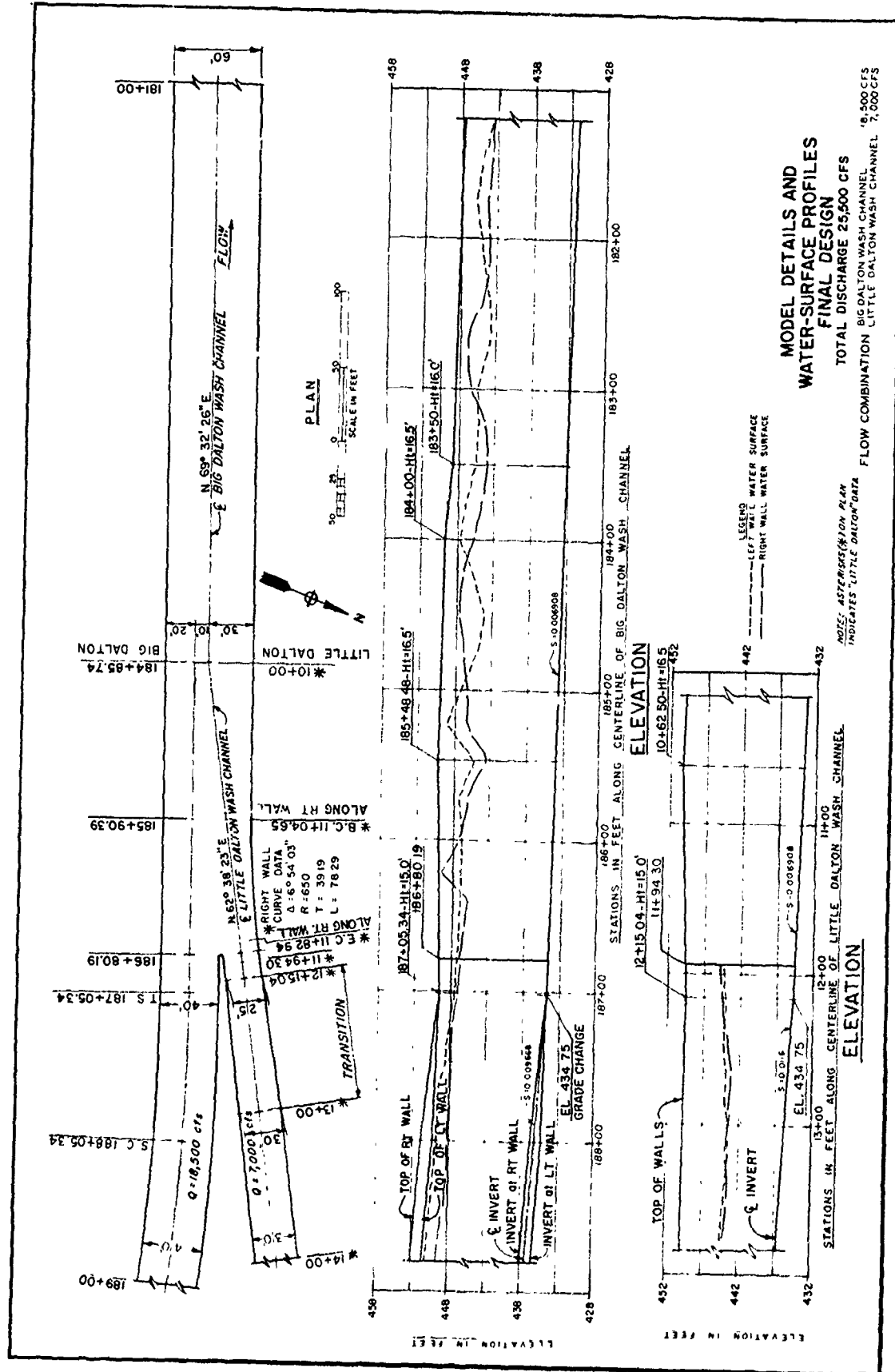
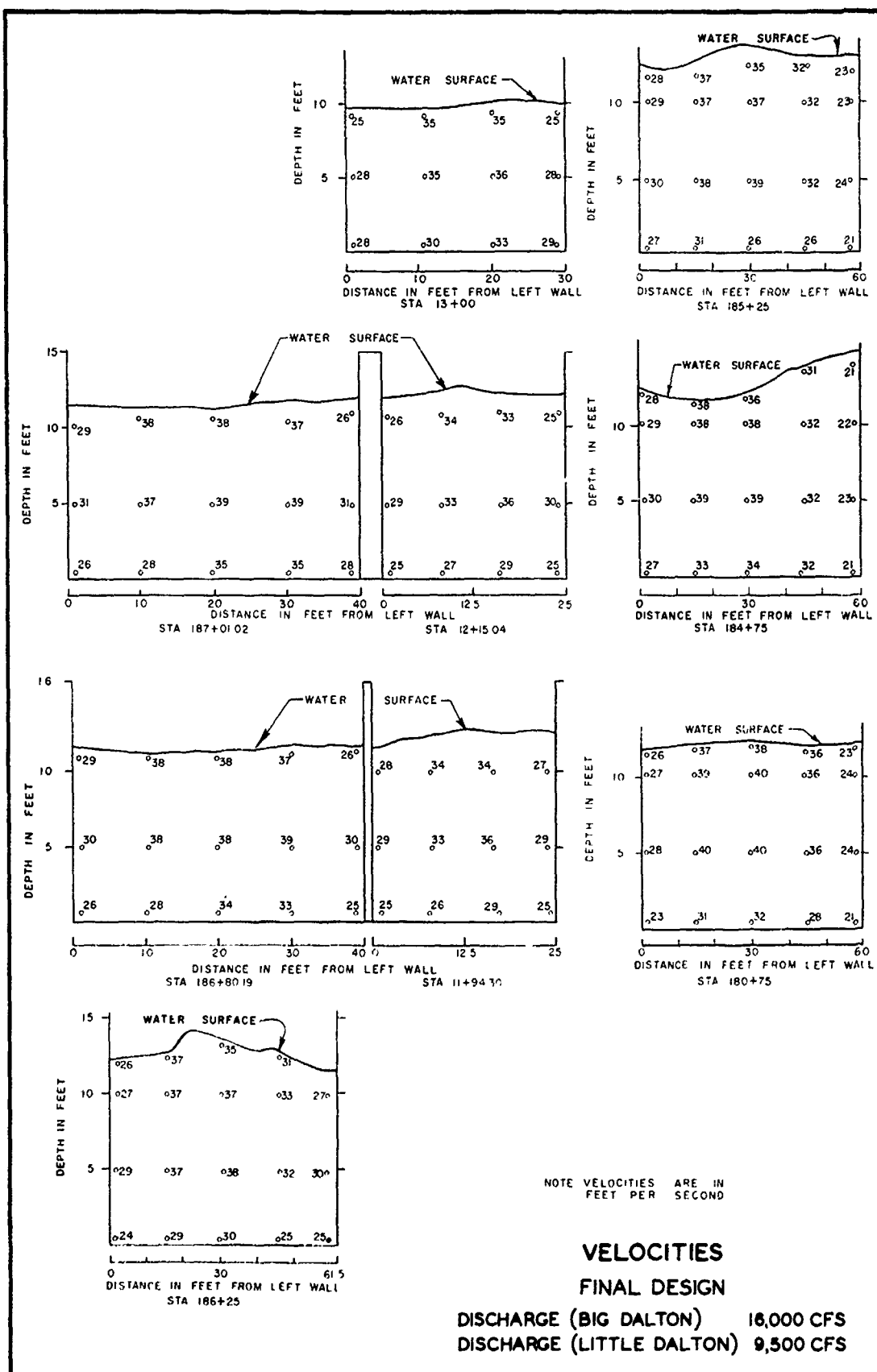
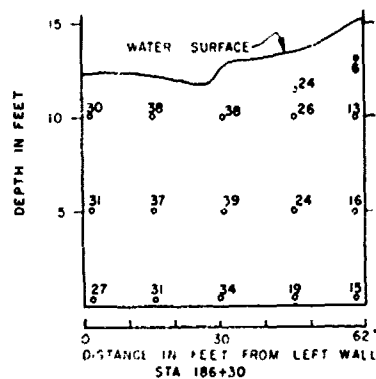
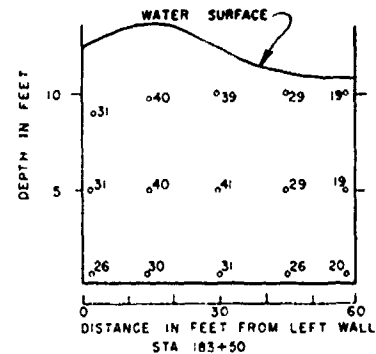
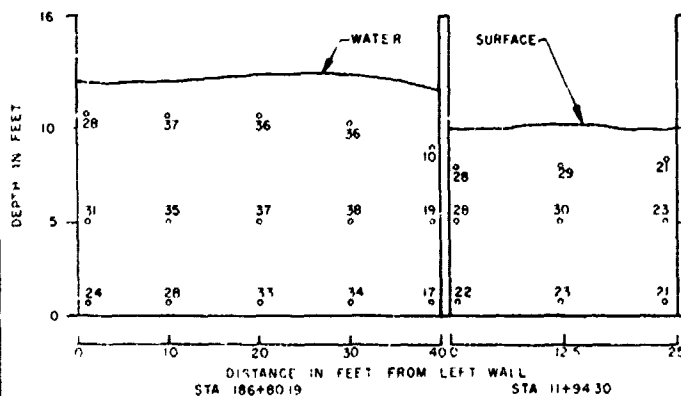
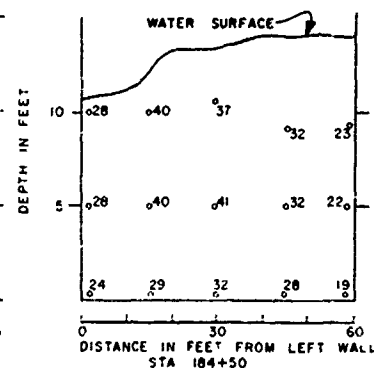
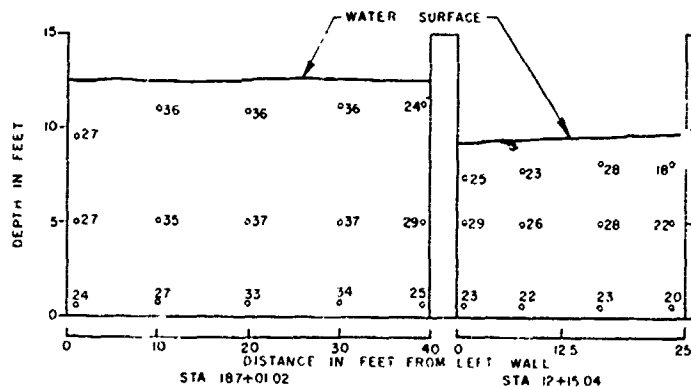
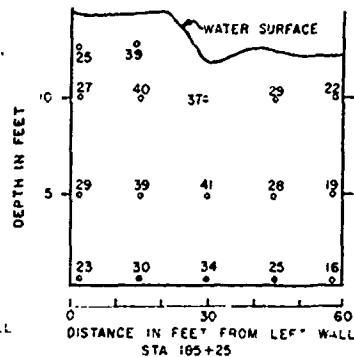
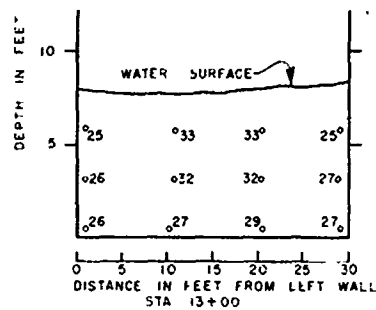


PLATE 8







NOTE VELOCITIES ARE IN
FEET PER SECOND

VELOCITIES

FINAL DESIGN

DISCHARGE (BIG DALTON) 18,500 CFS
DISCHARGE (LITTLE DALTON) 7,000 CFS

UPPER SAWTELLE-WESTWOOD SYSTEM
SAWTELLE BRANCH--WESTWOOD BRANCH

The Prototype

24. The upper unit of the Sawtelle-Westwood system from Moraga Drive, sta 397+00, to Charnock Road, sta 111+00, consists of two branches, one of which includes the Sepulveda Canyon channel. The Sawtelle Branch is both an open and covered rectangular concrete channel, and the width of the invert varies from 12 to 22 ft. The Sawtelle Branch is designed for discharges ranging from 2600 cfs at the upstream end to 4100 cfs at the confluence structure. The Westwood Branch, which includes Sepulveda Canyon channel, also comprises an open and covered rectangular concrete channel, and the width of the invert varies from 12 to 38 ft. The Westwood Branch is designed for discharges ranging from 3,800 cfs at the upstream end to 10,000 cfs at the confluence structure. The two branches merge at sta 118+69.96 on the Westwood Branch channel and at sta 10+25.21 on the Sawtelle Branch channel. The downstream limit of the confluence structure is at sta 116+46.34. The width of confluence ranges from 61.5 ft at the upstream end to 50 ft at the downstream end. The main Sawtelle-Westwood channel is an open rectangular concrete channel with an invert width of 50 ft and is designed for a 13,000-cfs discharge.

25. In addition to the Sawtelle-Westwood confluence, a side drainage confluence structure was located at sta 299+00 just downstream from Wilshire Blvd. in the Westwood Branch channel. It was later relocated downstream at sta 278+64.63 (Plate 11). This side drainage structure is herein designated as the Wilshire Side Drains. The drains are each 6.75 ft wide by 13 ft high and each is designed to carry 1200 cfs.

The Model

26. The general purpose of the model was to check the adequacy and effectiveness of the proposed design and, where undesirable flow

conditions were disclosed, to modify the original design by experimental means. The model, constructed to a scale ratio of 1:20, reproduced 475 ft of the Sawtelle Branch, 580 ft of the Westwood Branch, the confluence, and 546 ft of the main Sawtelle-Westwood channel. Originally, the design of the downstream end of the divider wall called for an 18-in. semicircular nose (Photo 16). However, because the junction of flow from the two branches resulted in the formation of waves in the confluence which were observed to continue downstream, the divider wall was extended downstream until a 12-in. semicircular (Photo 17) nose was formed. This 12-in. nose eliminated most of the waves.

27. Tests in the model were conducted with two combinations of flow: one, a discharge of 10,000 cfs in the Westwood Branch channel and 3000 cfs in the Sawtelle Branch channel; the other, a discharge of 8900 cfs in the Westwood Branch channel and 4100 cfs in the Sawtelle Branch channel. Flow conditions were observed throughout the entire reach, particular attention being given to the flow at the junction of the two branches and the confluence structure.

28. Model investigations showed flow conditions in the confluence and in the main channel downstream to be generally satisfactory for both combinations. Waves were set up, but nowhere along the channel did the waves overtop the walls. This is illustrated in Photos 18 and 19 with the 18-in. semicircular nose for the two combinations and in Photos 20 and 21 with the 12-in. semicircular nose. The water-surface profiles were measured using only the 18-in. semicircular nose and they are identified in Plates 12 and 13. However, the design with the 12-in. semicircular nose was recommended for the prototype.



Photo 16. Original design, 18-in. semicircular nose; looking upstream from sta 115+50, Sawtelle-Westwood channel



Photo 17. Final design, 12-in. semicircular nose; looking downstream from sta 12+00, Sawtelle Branch



Looking downstream from sta 120+00, Westwood Branch

Photo 18. Original design flow conditions, 18-in. semicircular nose;
Sawtelle Branch 3,000 cfs, Westwood Branch 10,000 cfs



Looking upstream from sta 116+00



Looking downstream from sta 11+50, Sartelle Branch

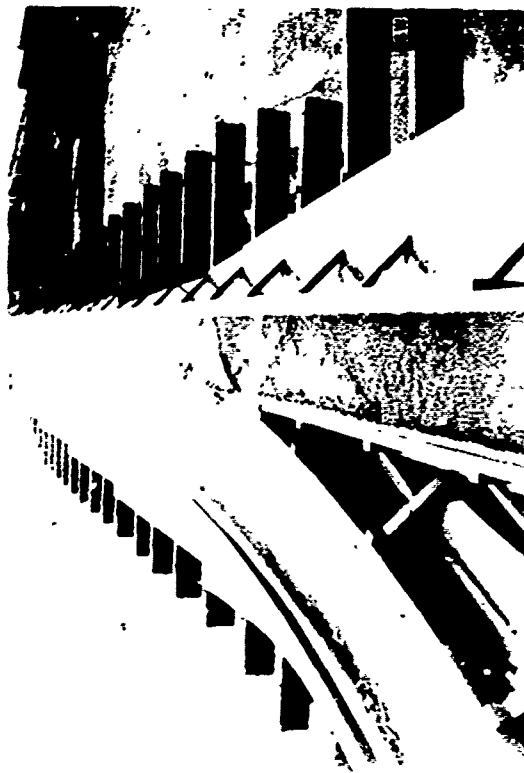
Photo 1.

Original design flow conditions, 18-in. semicircular nose;
Sartelle Branch 4100 cfs, Westwood Branch 8,900 cfs



Looking downstream from sta 120+00, Westwood Branch

-26-56

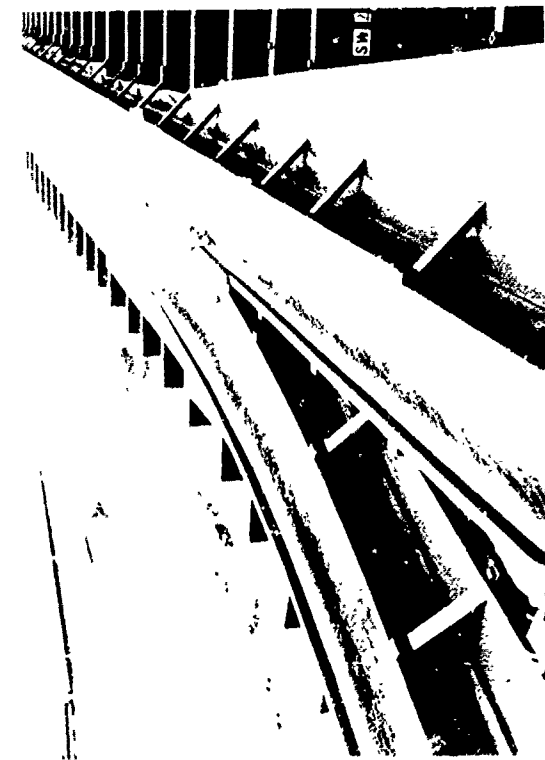


Looking downstream from sta 13+00, Saxtelle Branch

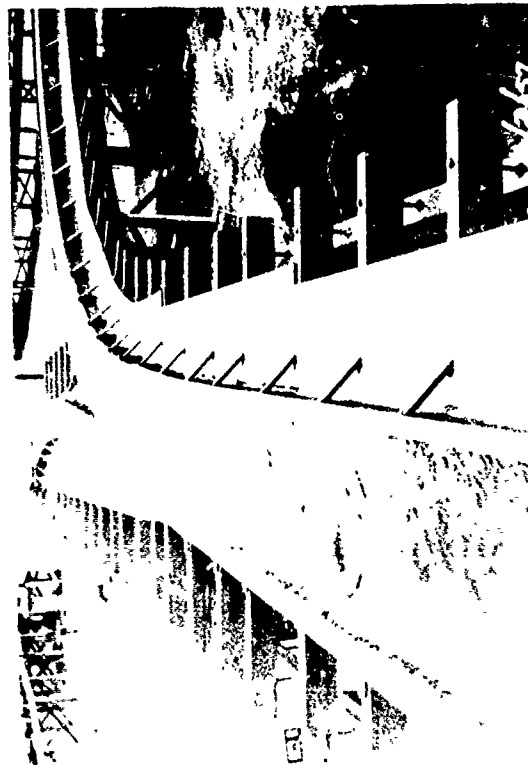


Looking upstream from right wall sta 116+50,
Saxtelle-Westwood channel

Photo 20. Final design flow conditions, 12-in. semi-circular nose;
Saxtelle Branch 3,000 cfs, Westwood Branch, 10,000 cfs

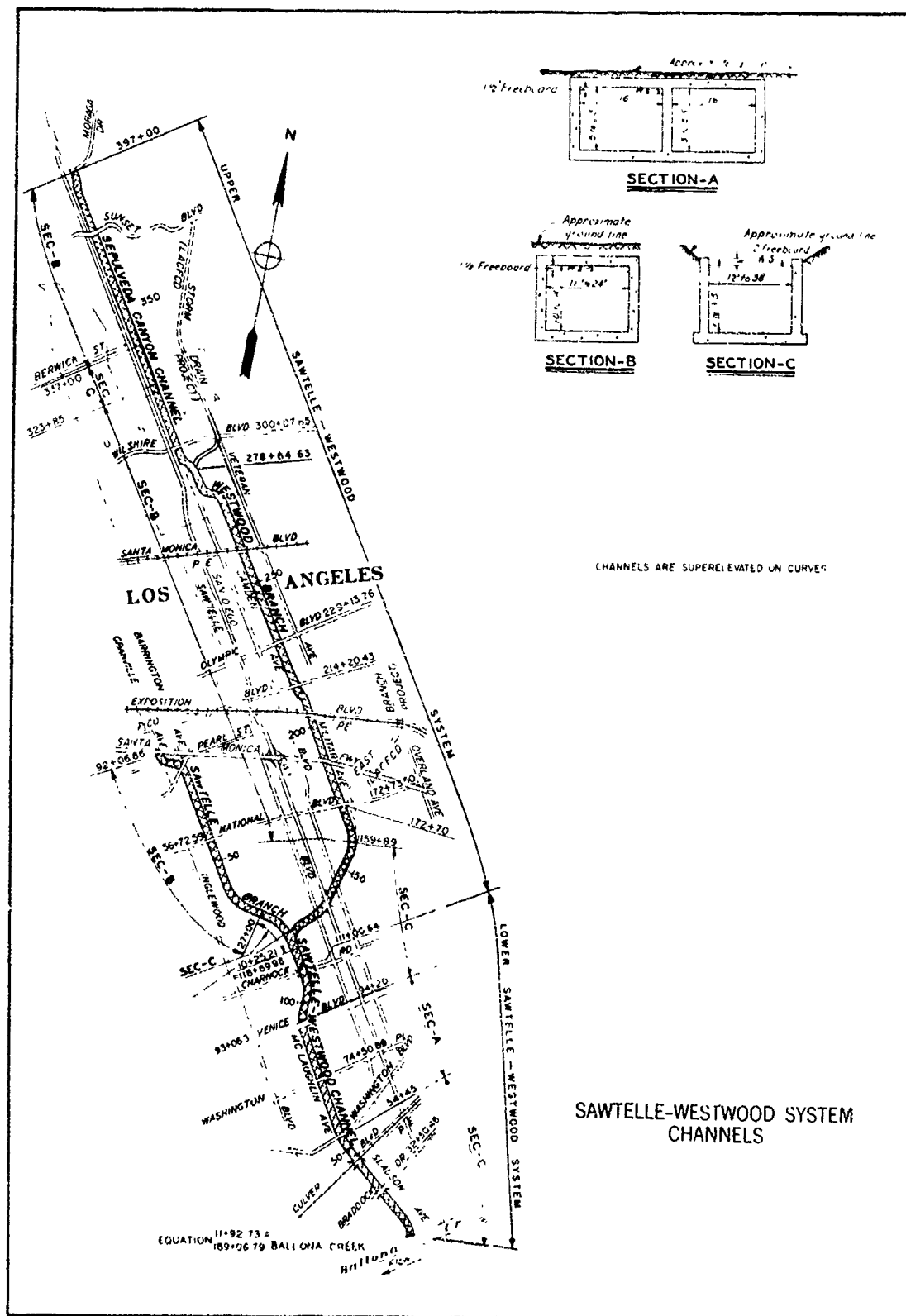


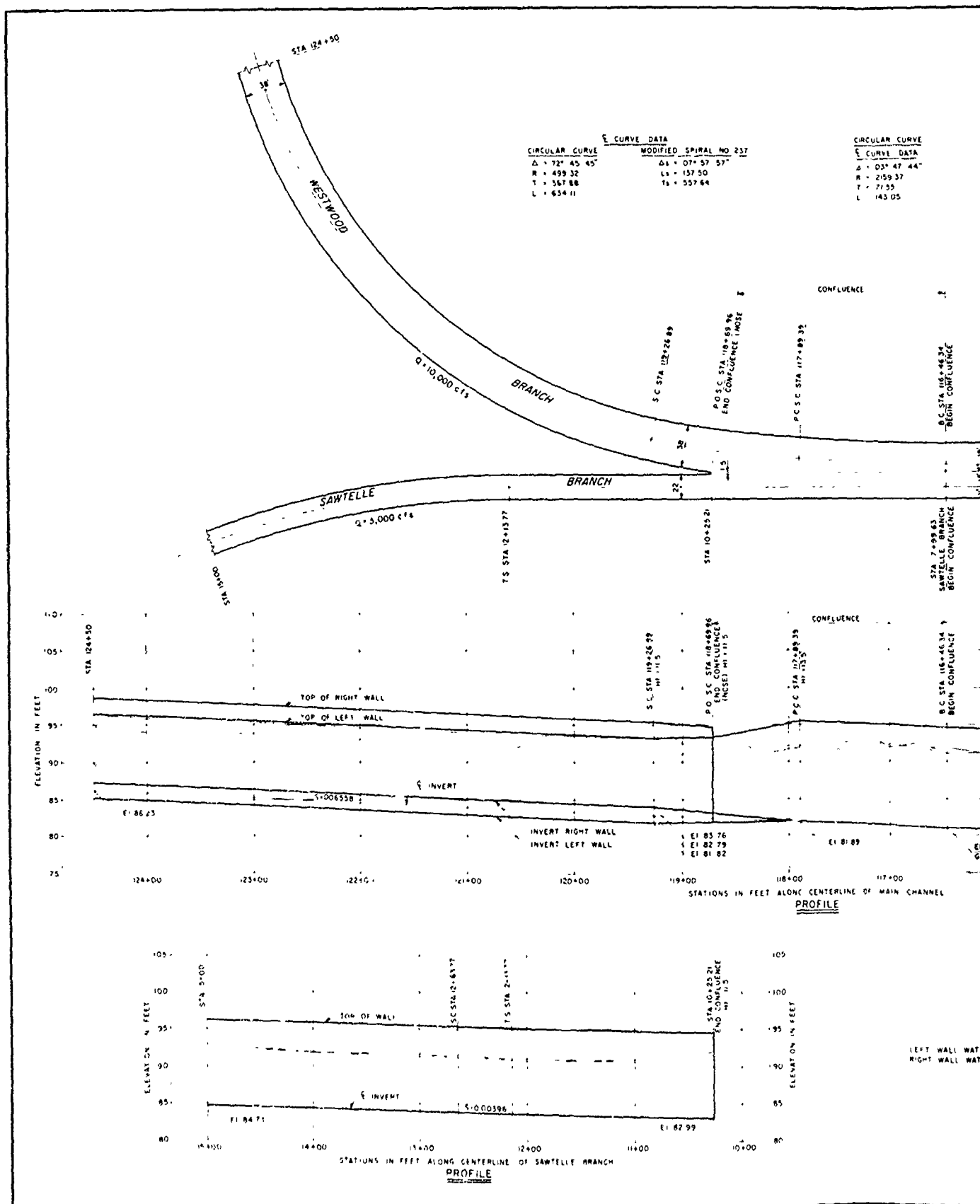
Looking downstream from sta 12+00, Sawtelle Branch

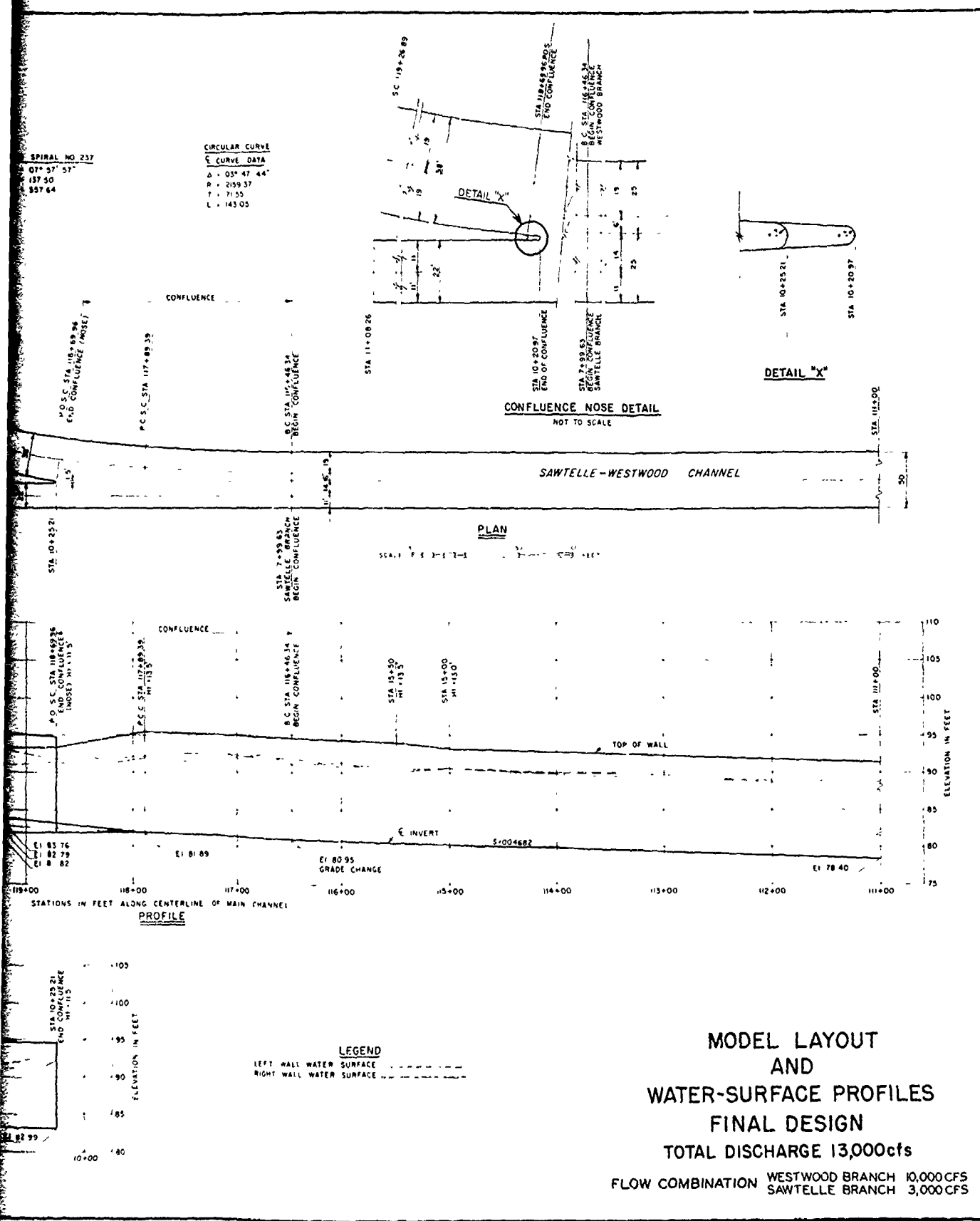


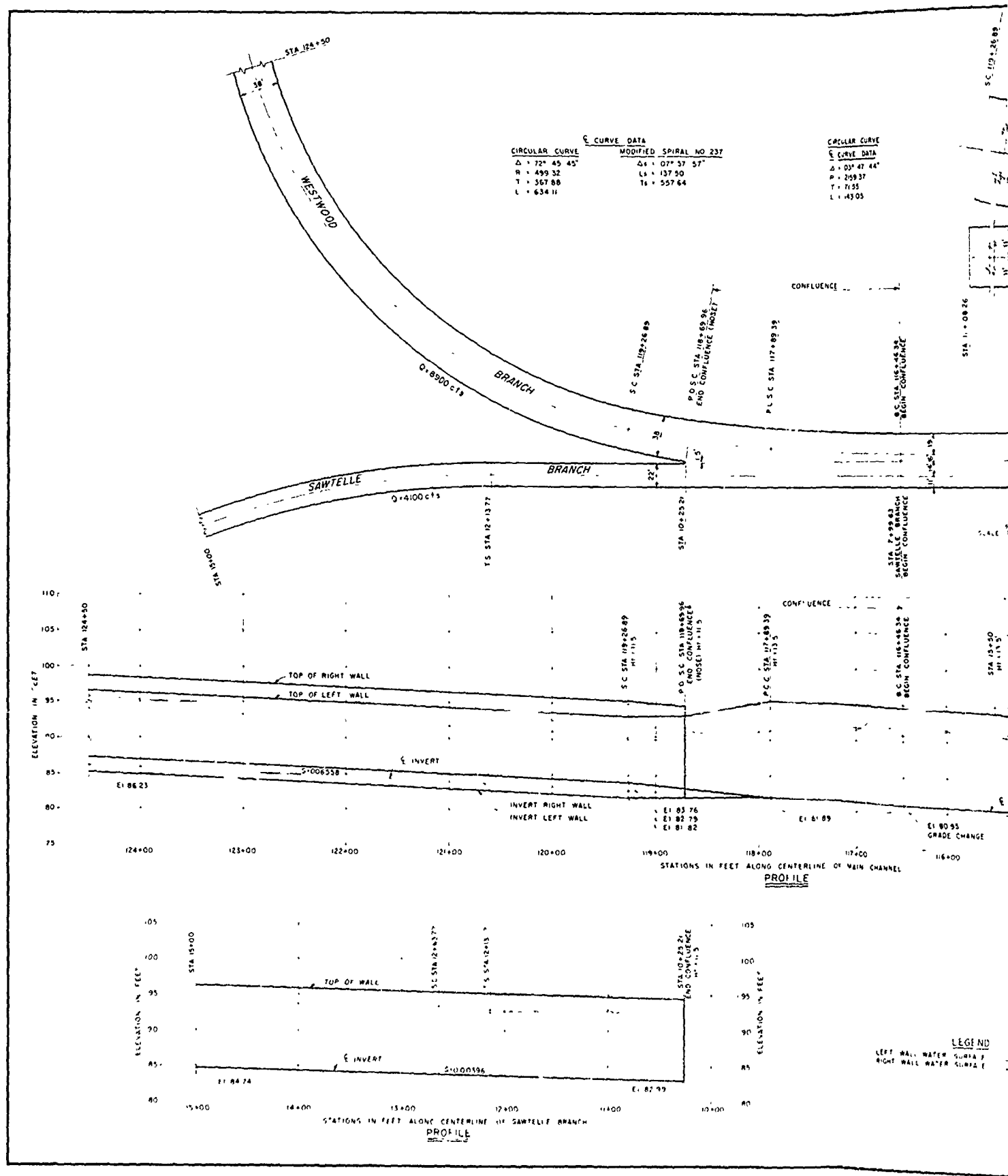
Looking upstream from sta 113+00,
Sawtelle-Westwood channel

Photo 21. Final design flow conditions, 12-in. semicircular nose;
Sawtelle Branch 4100 cfs, Westwood Branch 2000 cfs



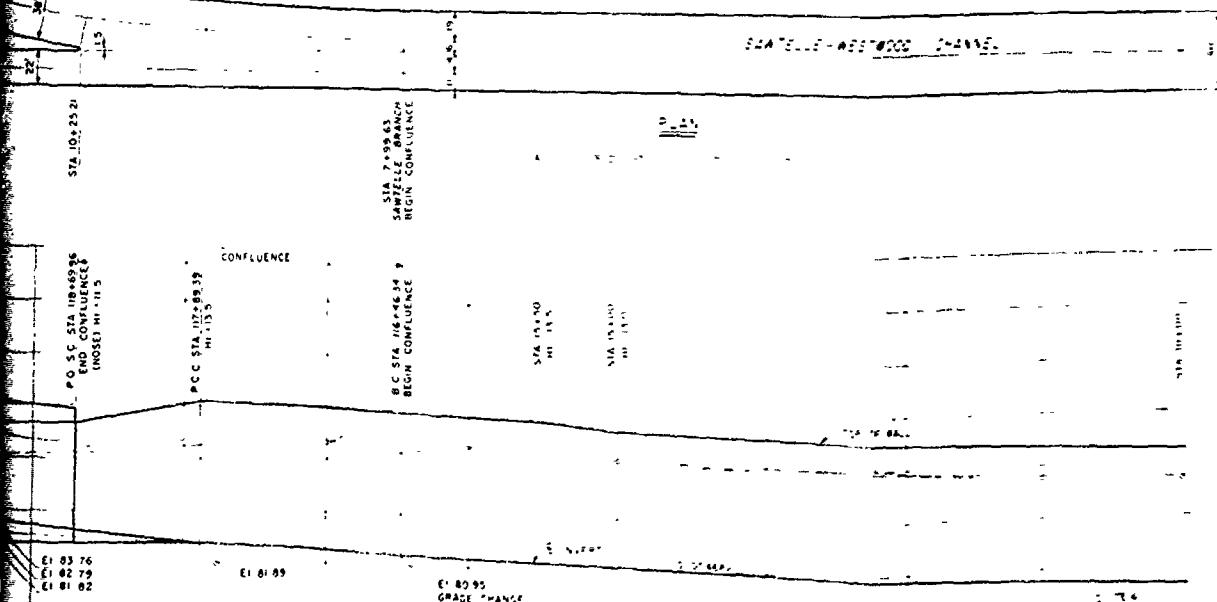
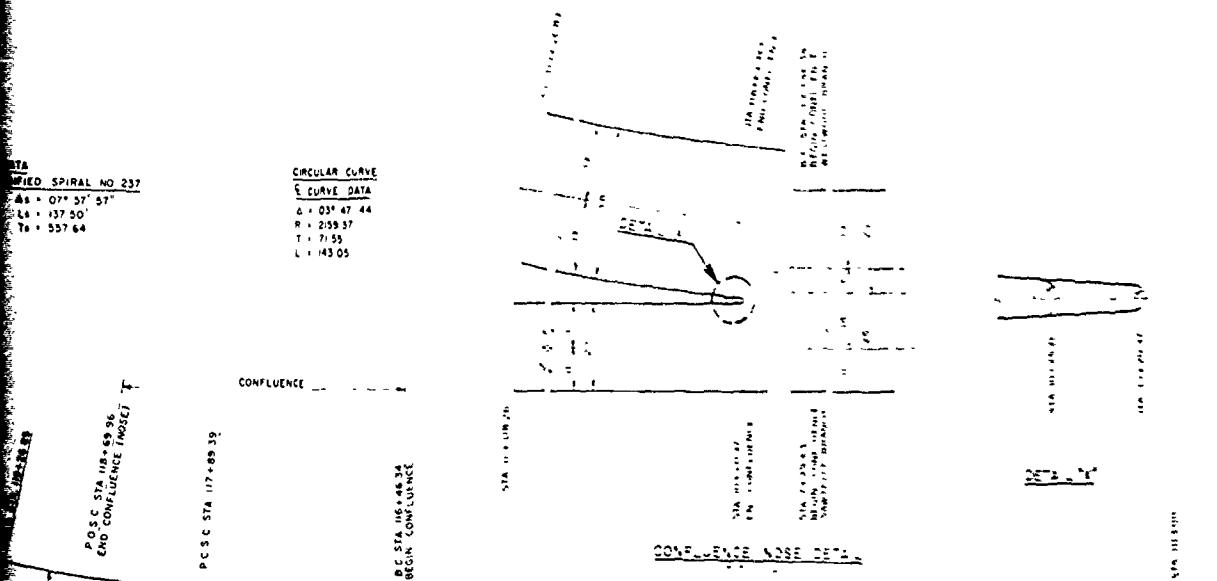






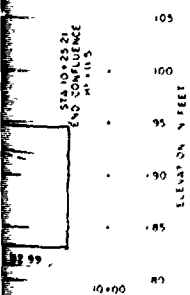
STA
SPIRAL NO 237
As = 07° 57' 57"
LA = 137° 50'
Ts = 557.64

CIRCULAR CURVE
C CURVE DATA
Δ = 03° 47' 44"
R = 259.37
T = 71.53
L = 143.05



STATIONS IN FEET ALONG CENTERLINE OF MAIN CHANNEL

PROFILE



LEGEND
LEFT WA - WATER - WASTE
RIGHT WA - WASTE - WASTE

MODEL LAYOUT AND WATER-SURFACE PROFILES FINAL DESIGN

TOTAL DISCHARGE 13,000 cfs

FLOW COMBINATION WESTWOOD BRANCH - 8,000 cfs
SAMIZELLE BRANCH - 5,000 cfs

UPPER SAWTELLE-WESTWOOD SYSTEM
WESTWOOD BRANCH CHANNEL-WILSHIRE SIDE DRAINS

The Prototype

(For a description of the prototype, see paragraph 24.)

Original Design

29. The Westwood Branch channel, upstream from the junction with the Wilshire Side Drains, is a 12.5-ft-high by 12-ft-wide rectangular channel designed to carry a discharge of 4800 cfs. The right side drain is a 10.25-ft-high by 12.75-ft-wide rectangular conduit; it enters the main channel at sta 299+00. At the end of the divider wall where the main channel and the right side drain come together, the total width of the main channel is 25.75 ft. The left side drain is a 10.25-ft-high by 14-ft-wide rectangular conduit. The center wall of the two side drains continues downstream as a training wall and terminates at sta 297+45. At the end of the training wall, the main channel and the left side drain are 16 and 8 ft wide, respectively, making a total channel width of 25 ft at this point. The left wall converges from this width toward the channel centerline to a width of 18 ft at sta 294+65 (Photo 22).

30. This design was tested with two discharge combinations: (a) 4800 cfs in the Westwood Branch channel, 1260 cfs in the left side drain, and 1140 cfs in the right side drain, making a combined discharge of 7200 cfs at the end of the confluence; and (b) 3500 cfs in the Westwood Branch channel, with the same design discharges in both side drains (1260 and 1140 cfs), making a total combined discharge at the end of the confluence of 5900 cfs. Disturbance to the main channel flow was relatively minor for the combined discharge of 7200 cfs (Photo 23). The other combination for a discharge of 5900 cfs showed the formation of waves downstream from the confluence (Photo 24). These waves did not overtop the design wall downstream from the

confluence. Plates 14 and 15 show detailed dimensions and water-surface profiles of the channel design.

Alternative Design

31. The proposed prototype design was relocated a considerable distance downstream from its original location. Therefore, a new design was adopted which consisted of narrowing the widths of side drains to 8.5 ft. The junction was then located at sta 278+64.63, the main channel at the end of the divider wall was 13 ft wide, and the end of training wall was at sta 276+54.63. At this point, the main channel was 18 ft wide and the left side drain, 7.5 ft wide. At a point 50 ft downstream from the end of the training wall, the channel was narrowed to 24 ft. From sta 276+04.63 the left wall converged, reducing the width of channel to 22.5 ft at sta 274+84.63. Between sta 272+00 and 271+00 the invert again converged from 22.5 ft to 18 ft wide. This design is shown in Plate 16 and Photo 25.

32. The test, conducted with a design discharge combination of 4800 cfs in the main channel and 1200 cfs in each side drain, showed that at the beginning of the confluence there was a slight drawdown of the water surface in the main channel and an undulating hydraulic jump at the downstream end of each side drain. This was attributed to the differential in water-surface elevation between the side drains and the main channel. The undulating waves produced by the jump extended downstream for a distance of about 550 ft. Water-surface profiles are shown in Plate 16 and Photo 26.

Final Design

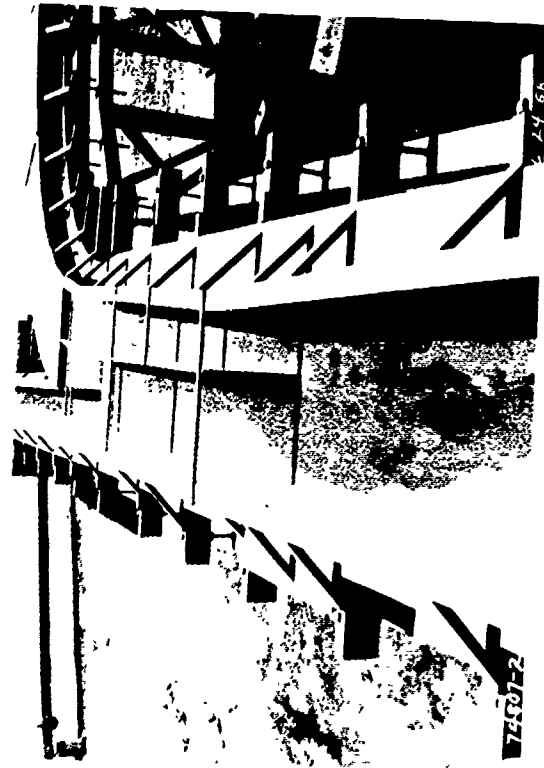
33. Savings could possibly be realized by reducing the width of side drains and main channel. In this recommended design, the side drains were 6.75 ft wide and the training wall was shortened to sta 277+14.63. The left side drain at the end of the training wall was 6.25 ft wide; the main channel at this location was 17.0 ft wide.

From the end of the training wall, the left wall was flared in toward the centerline in several locations to reduce the width of channel as much as feasible. Water-surface profiles are shown in Plate 17.

34. This adopted design was found to be most effective and is shown in Plate 17 and Photo 27.

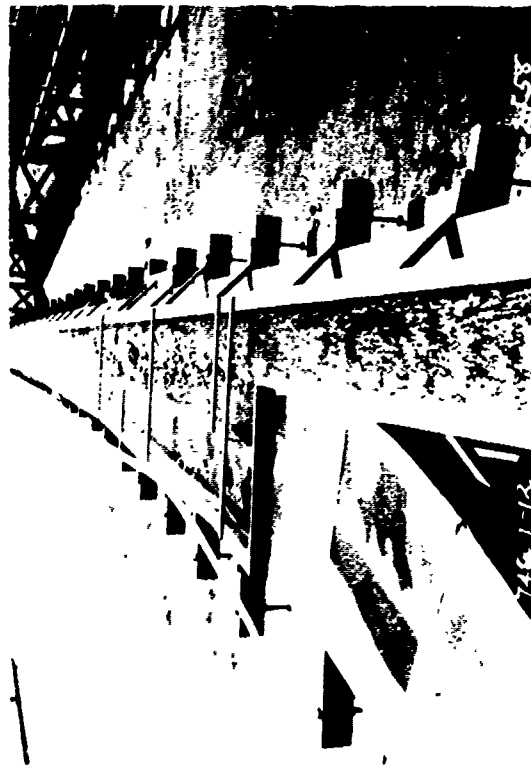


Looking downstream



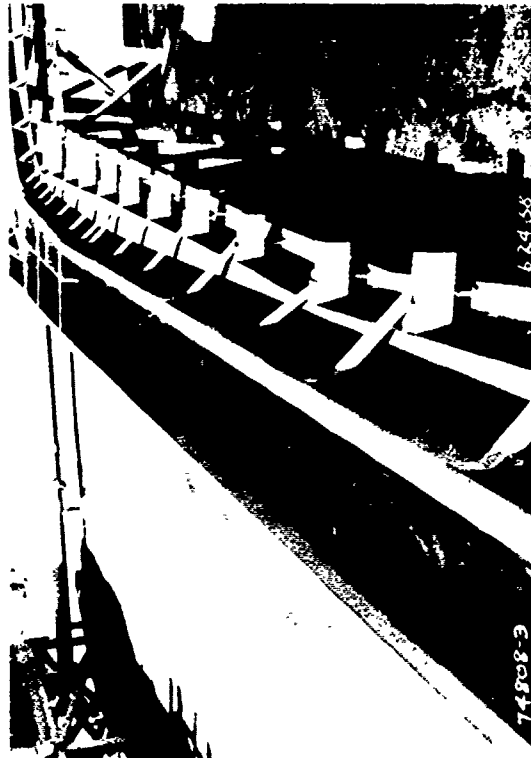
Looking upstream from sta 295+50

Photo 22. Original design, Westwood channel-Wilshire side drains



Looking downstream

Photo 23. Original design flow conditions; Westwood channel 4800 cfs, right side drain 1140 cfs, and left side drain 1260 cfs



Looking upstream from sta 293+50

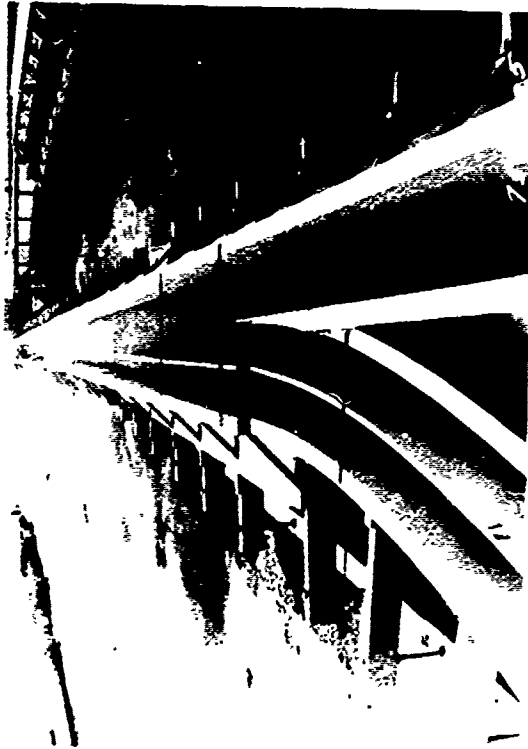


Looking downstream from sta 300+50



Looking upstream from sta 294+00

Photo 24. Original design flow conditions; Westwood channel 3500 cfs, right side drain 1140 cfs, and left side drain 1260 cfs

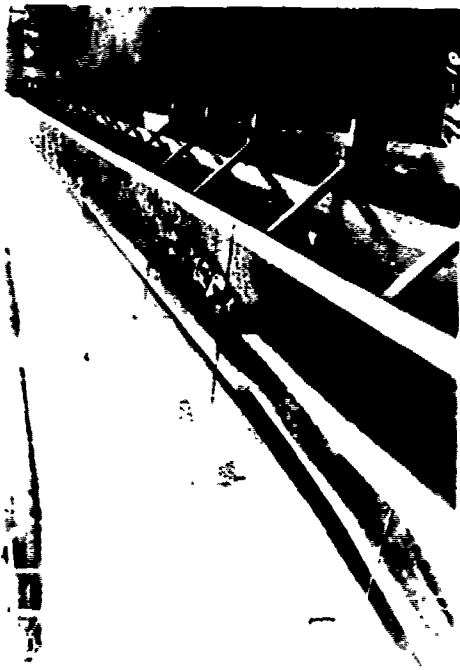


Looking downstream



Looking upstream from sta 274+00

Photo 25. Alternative design



Looking downstream from Westwood channel



Looking upstream from sta 274+00
Photo 26. Alternative design flow conditions; Westwood channel 4800 cfs,
left and right side drains 1200 cfs each.

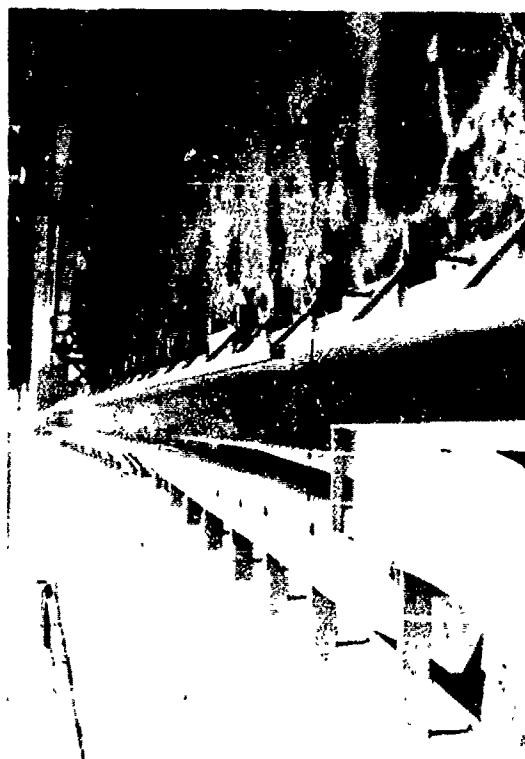
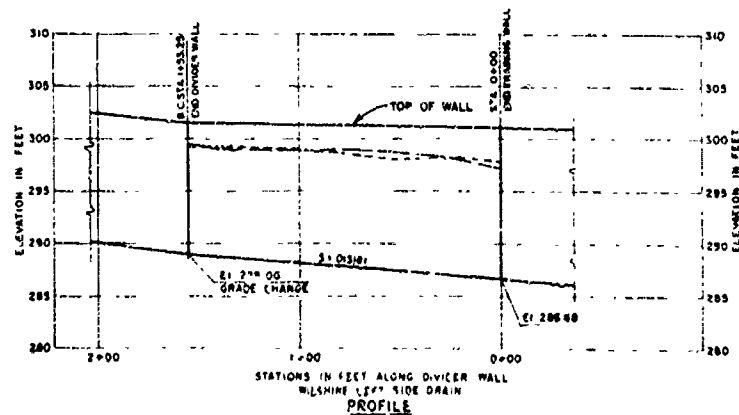
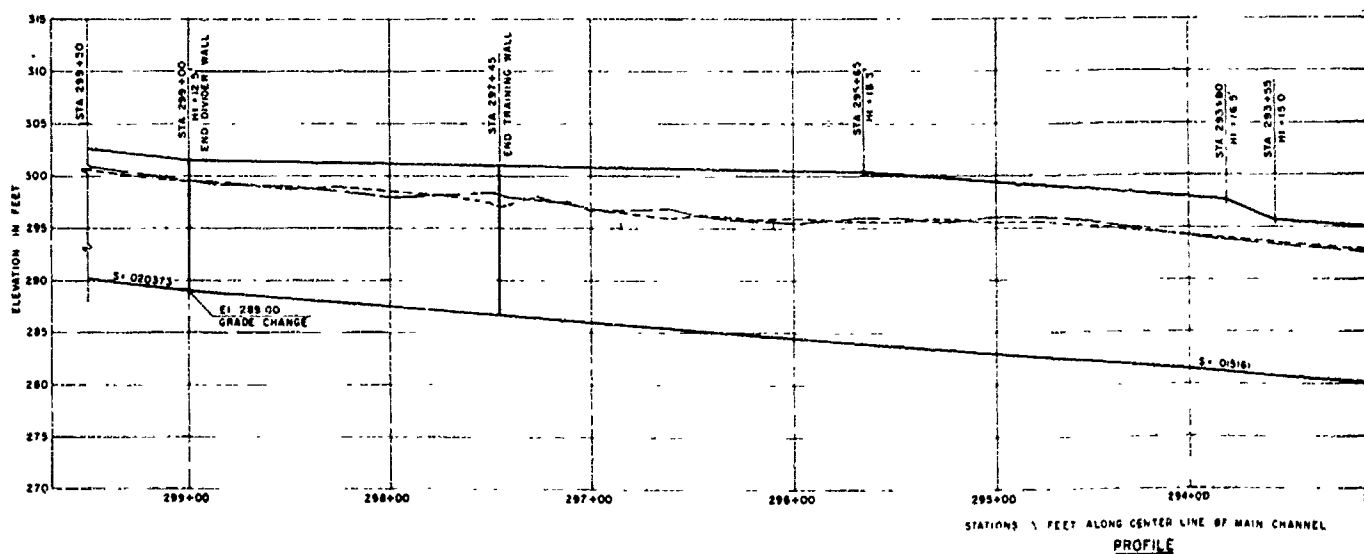
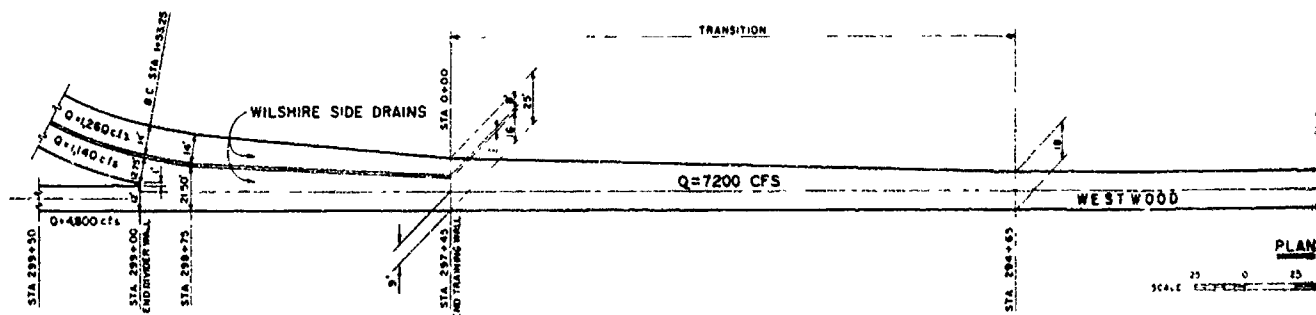
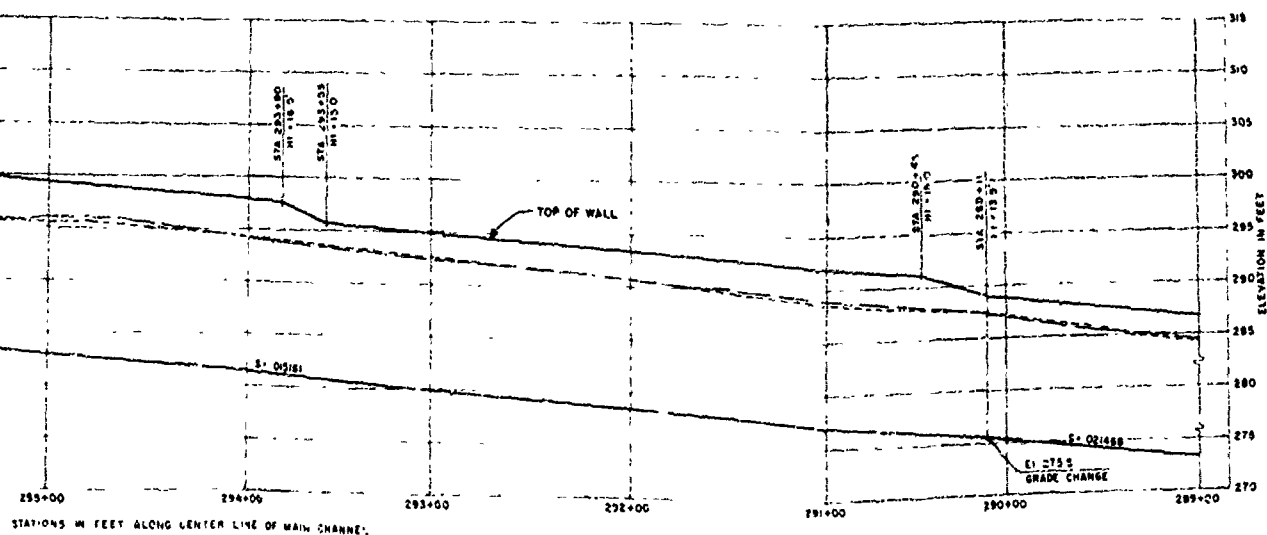
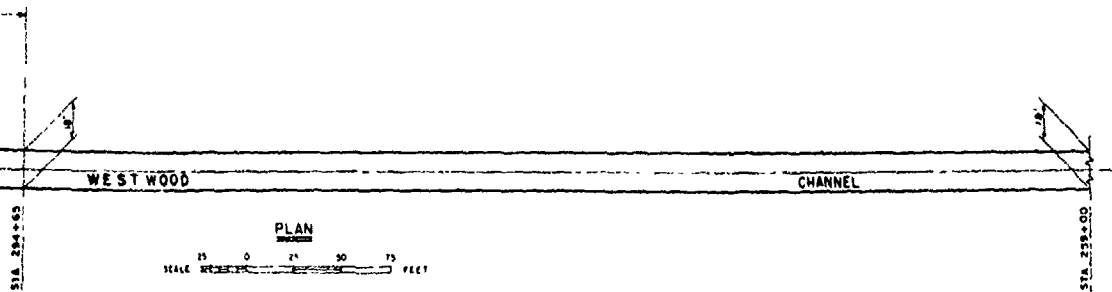


Photo 27. Final design, looking downstream,
Westwood channel-Wilshire side drains



LEFT WALL
RIGHT WALL

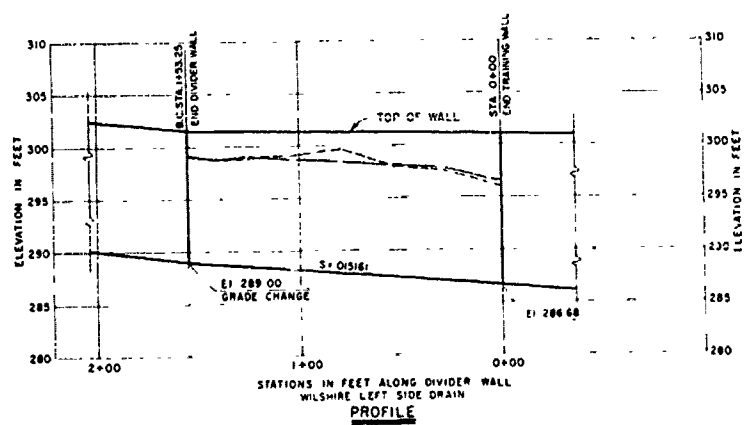
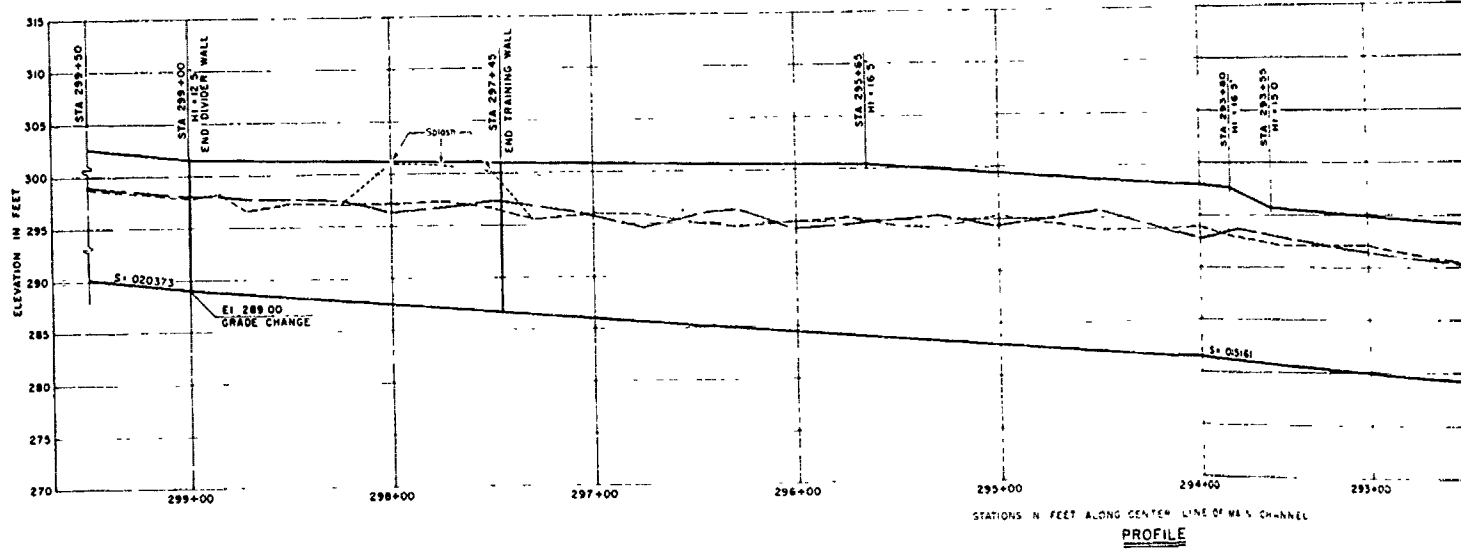
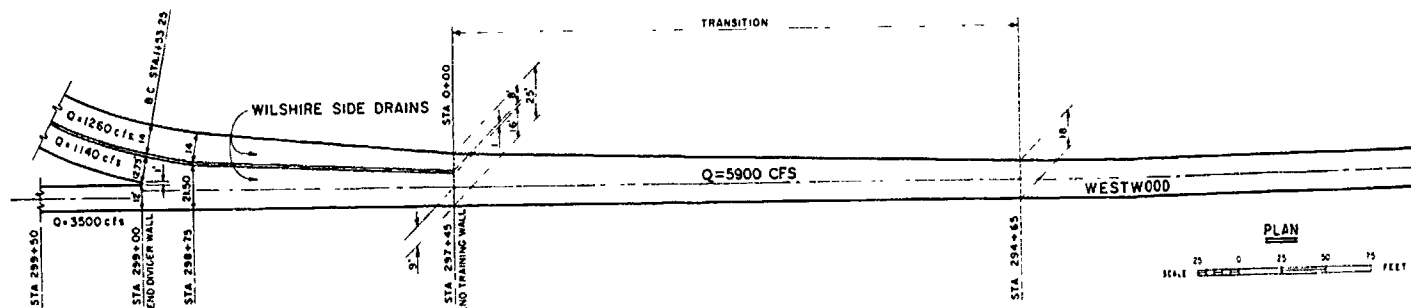


LEGEND

LEFT WALL WATER SURFACE

RIGHT WALL WATER SURFACE

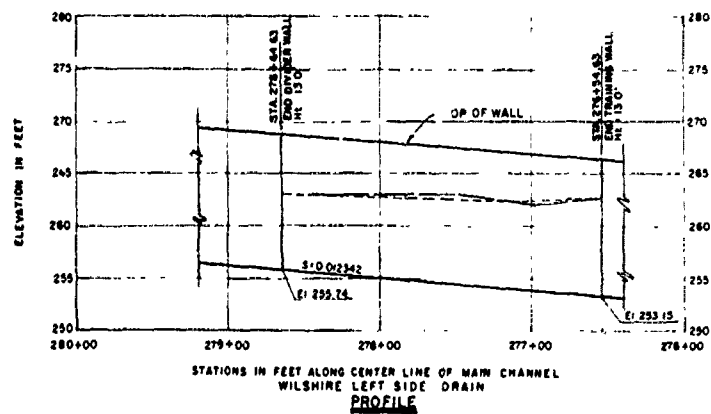
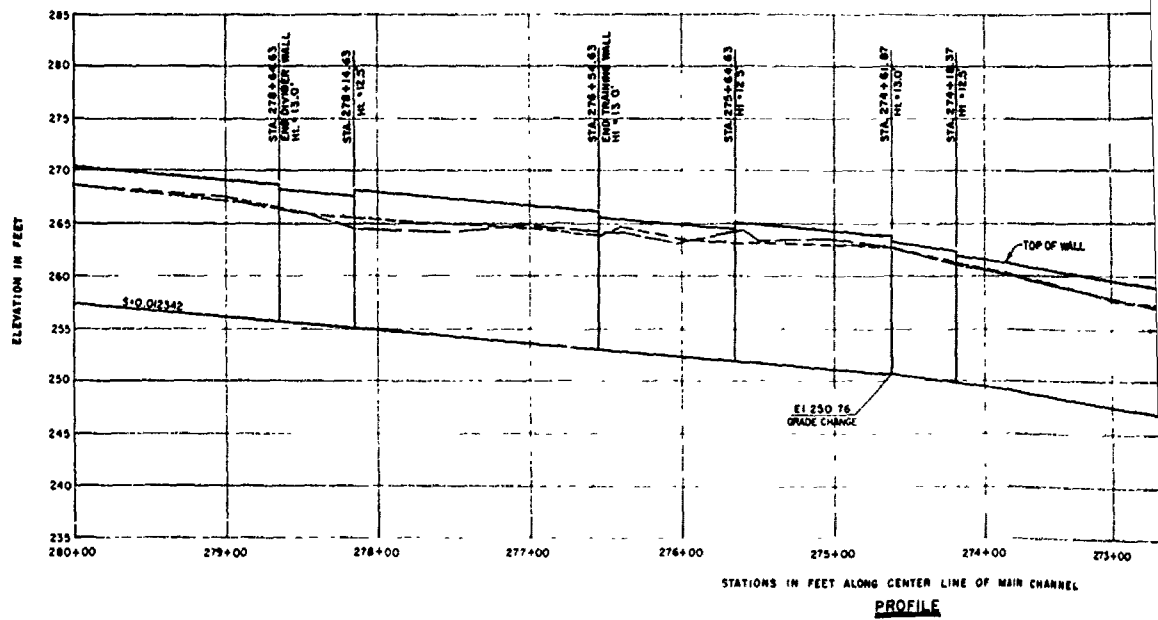
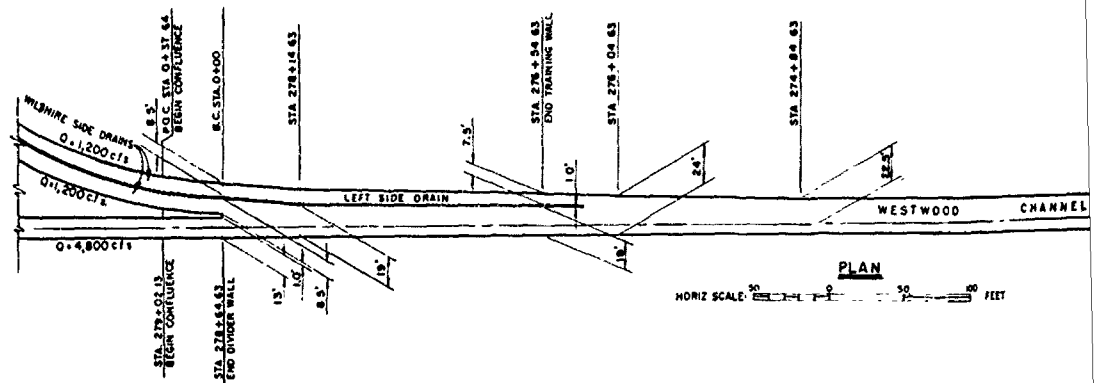
MODEL LAYOUT
AND
WATER-SURFACE PROFILES
ORIGINAL DESIGN
TOTAL DISCHARGE 7,200 cfs
FLOW COMBINATION: WESTWOOD CH 4800 CFS
WILSHIRE SIDE DRAINS 2400 CFS



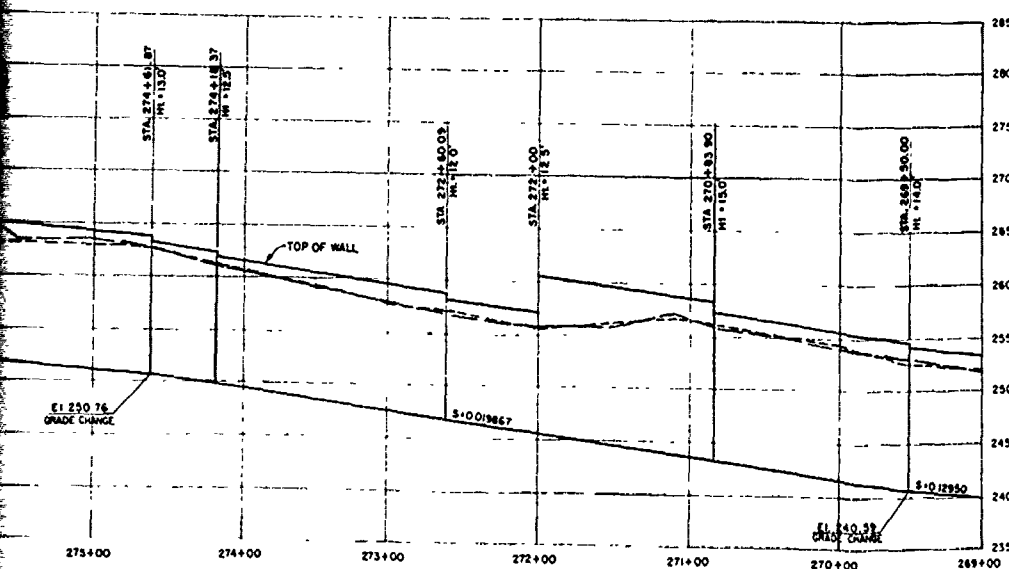
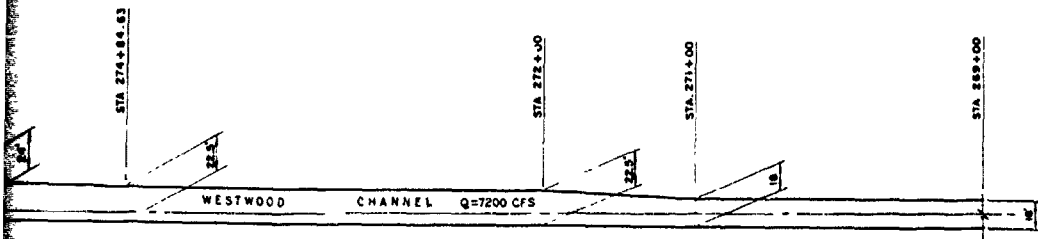
LEGEND

LEFT WALL WATER SURFACE - - -

RIGHT WALL WATER SURFACE - - -



LEFT WALL WATER
RIGHT WALL WATER

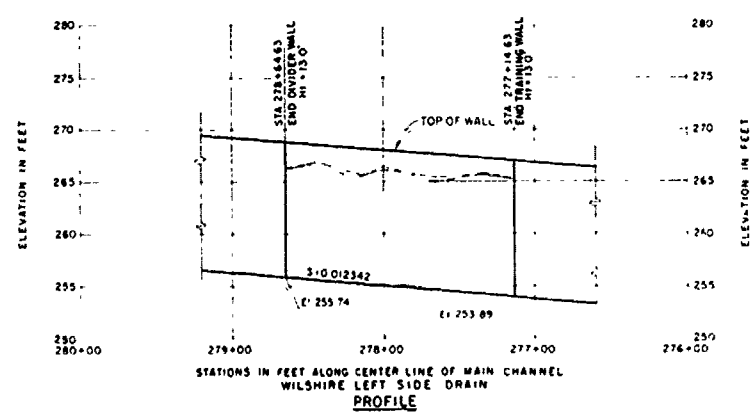
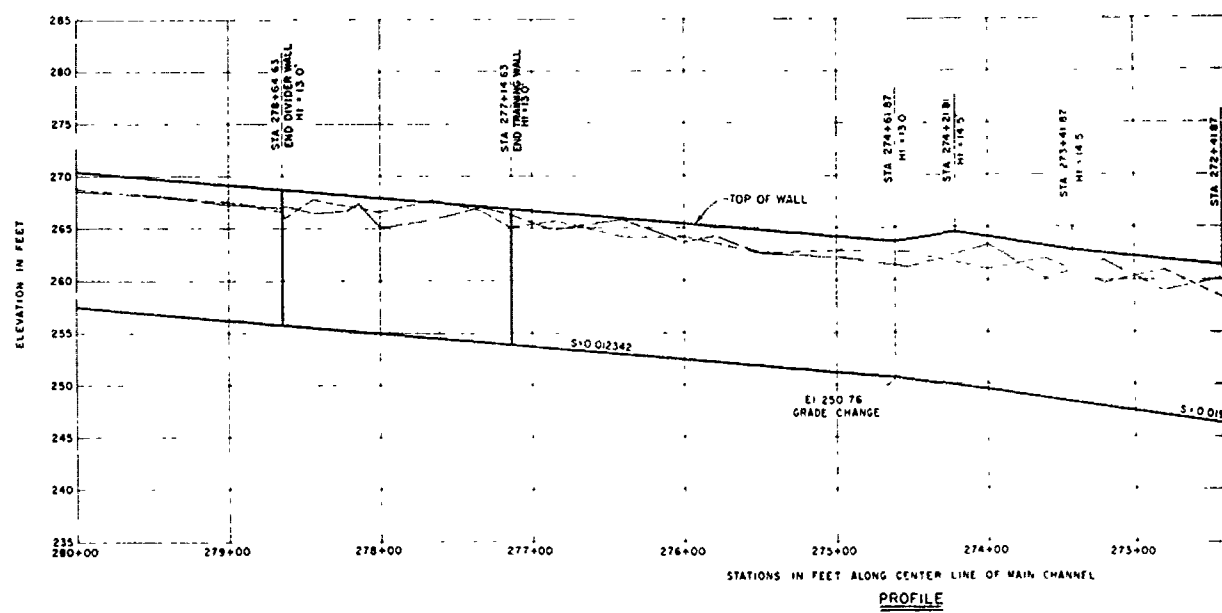
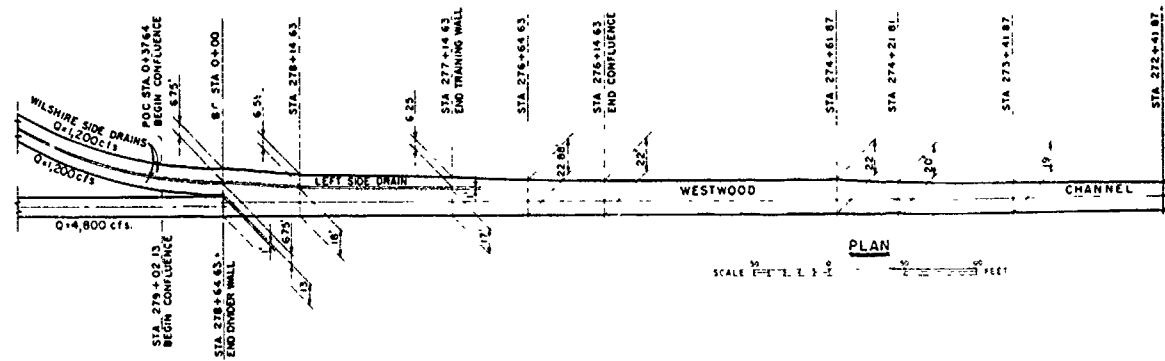


LEGEND

LEFT WALL WATER SURFACE -----

RIGHT WALL WATER SURFACE -----

**MODEL LAYOUT
AND
WATER-SURFACE PROFILES
ALTERNATIVE DESIGN
TOTAL DISCHARGE 7,200 cfs**



LEGEND

LEFT WALL WATER SURFACE

RIGHT WALL WATER SURFACE

STA. 273+41.87

STA. 272+41.87

STA. 269+00.00

CHANNEL Q=7200 CFS

30 FEET

STA. 273+41.87
HI. 114.5

STA. 272+41.87
HI. 115.0

STA. 269+00.00
HI. 115.0

ELEVATION IN FEET

S+0.019867

S+0.012850

E1 240.59
GRADE CHANGE

274+00 273+00 272+00 271+00 270+00 269+00

RIGHT LINE OF MAIN CHANNEL

FILE

LEGEND

LEFT WALL WATER SURFACE ---
RIGHT WALL WATER SURFACE ---

MODEL LAYOUT
AND
WATER-SURFACE PROFILES
FINAL DESIGN
TOTAL DISCHARGE 7,200 cfs

PLATE 17

2

UPPER BURBANK-WESTERN SYSTEM
BURBANK-WESTERN CHANNEL - STOUGH CANYON

The Prototype

35. The Burbank-Western channel, one of the principal tributaries of the upper Los Angeles River, originates in the Verdugo Mountains northwesterly of the city of Burbank, flows southeasterly along the base of the mountain for several miles, then crosses the lower part of the San Fernando Valley, and is confluent with the Los Angeles River just upstream of Victory Boulevard. The channel serves as a collector for the runoff of the southerly slopes of the Verdugo Mountains from La Tuna Canyon to Stough Canyon and of portions of highly developed urban and suburban districts within the city boundaries of Los Angeles, Glendale, and Burbank.

36. Two major channels, tributary to the upper Burbank-Western channel, were proposed, namely the Stough Canyon channel and Hansen Heights channel. The Stough Canyon channel enters the Burbank-Western channel at sta 134+49.67 and Hansen Heights enters at sta 336+56.81. Burbank-Western channel, upstream from the Stough Canyon channel, is a rectangular covered section having a base width of 20 ft, wall heights of 18.5 ft, and an invert slope of 0.009859. The channel, which has a design capacity of 11,000 cfs, enters the junction at the midpoint of a 100-ft spiral curve. The Stough Canyon channel is a 9-ft-wide by 9-ft-high rectangular covered section with an invert slope of 0.0352. Stough Canyon channel, which has a design capacity of 2200 cfs, enters the junction with a 50-ft spiral curve. The Burbank-Western channel from the divider wall downstream is 30 ft wide and the design discharge for this main channel is 13,200 cfs.

37. The Hansen Heights channel joins the Burbank-Western channel at sta 336+56.81. Upstream from the confluence, the Hansen Heights channel is 20 ft wide and the Burbank-Western channel is 20 ft wide; downstream from the confluence, the Burbank-Western channel is 30 ft wide. The maximum depth of flow through the confluence structure will

occur when the discharge of 6500 cfs in Burbank-Western channel combines with the discharge of 2000 cfs in Hansen Heights channel.

Original Design

38. The model, built to an undistorted scale ratio of 1:20, was originally constructed as shown in Plate 18 and Photo 28. The invert of the two channels at the junction, sta 134+49.67, were at the same relative elevation. Invert superelevation was included at this point because the channels are confluent on a modified spiral curve.

39. The model indicated that the original design of the confluence was unsatisfactory. The flow conditions were entirely unsatisfactory due to the turbulence in the confluence section, resulting in objectionably high reflective waves downstream of the confluence. The freeboard just downstream of the confluence in this design was also inadequate (Photo 29). Water-surface profiles for the design discharges are shown in Plate 18.

Alternative and Final Designs

40. The undesirable conditions noted during the test of the original design indicated that some modifications and revisions would be required in order to obtain a satisfactory design for this confluence structure. The alternative design (Photo 30) involved the addition of an "L" type curtain wall extending vertically from the soffit of Stough Canyon channel. The bottom of the curtain wall, from the soffit of Stough Canyon channel, was flared from a width of 9 ft at sta 134+49.67 and extended 90 ft downstream where it intersected the left wall of the main channel. The 30-ft-wide channel was maintained throughout the downstream section of the main channel. No changes were made in either the Burbank-Western or Stough Canyon channels upstream from the confluence. Flow conditions at the junction were improved considerably with the curtain wall (Photo 31). The reflective waves noticed in the original design were reduced; however, the curtain wall was not

feasible. Therefore, a new design concept was adopted which consisted of having the invert of Stough Canyon channel at the junction raised approximately 8 ft above the invert of Burbank-Western channel. The invert of Stough Canyon channel from sta 134+49.67 continues downstream, tapering toward the left wall where it diminishes at about sta 133+54.56. Plate 19 and Photo 32 show the final design. Plate 20 shows the comparison details between the original and final design. The tests of this revised confluence showed considerable improvement over the previous designs and indicated that the desired design had been obtained. Flow conditions in the confluence and in the main channel downstream were much improved. Water-surface profiles measured with the combined discharge of 13,200 cfs for this design are shown in Plate 19. Flow conditions are shown in Photo 33, and velocity distributions of various cross sections are shown in Plate 21.

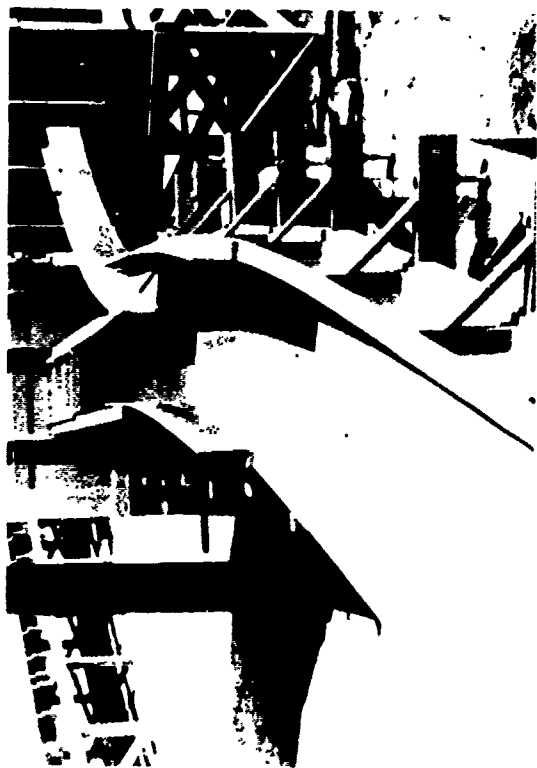
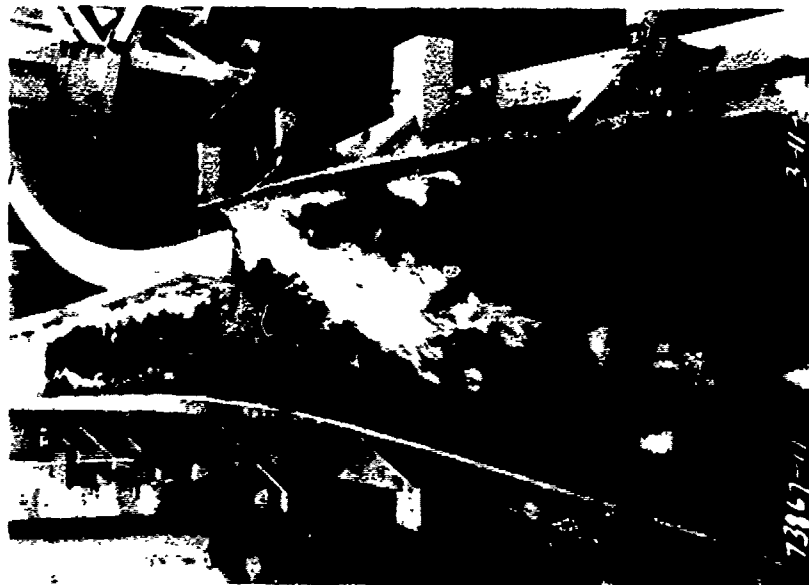


Photo 23. Original design, looking upstream at
Burbank-Western - Stough Canyon channel confluence



Looking downstream

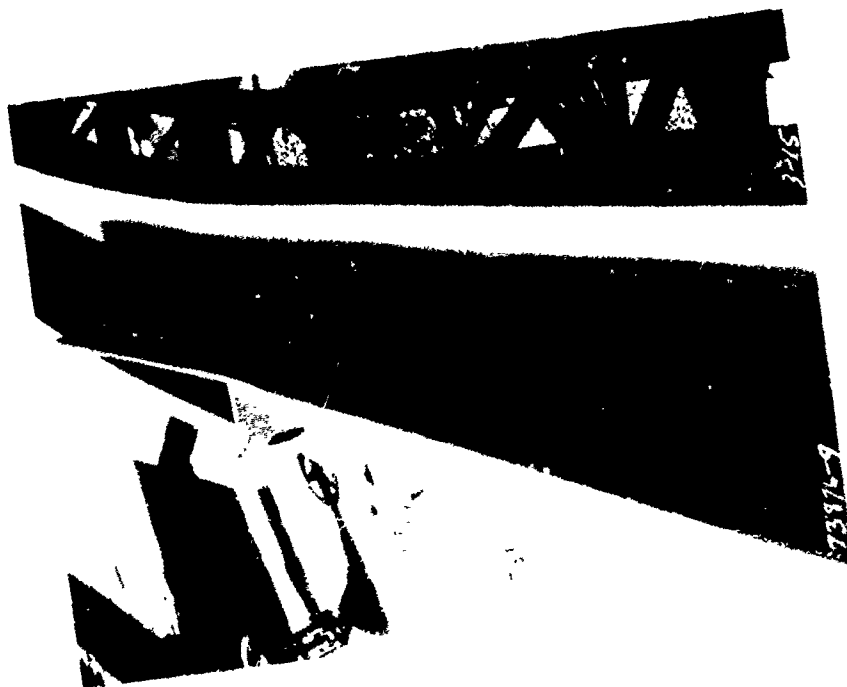


Looking upstream

Photo 29. Original design flow conditions;
Burbank-Western 11,000 cfs, Stough Canyon channel 2,200 cfs

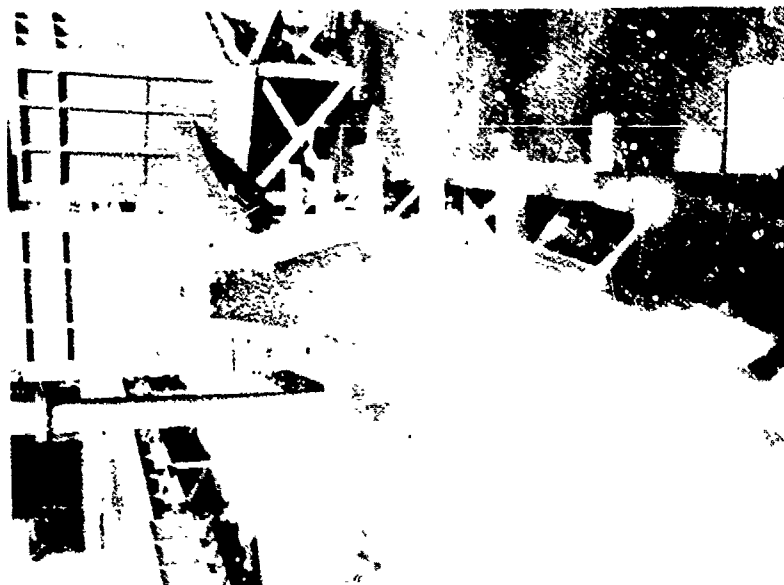


Looking upstream

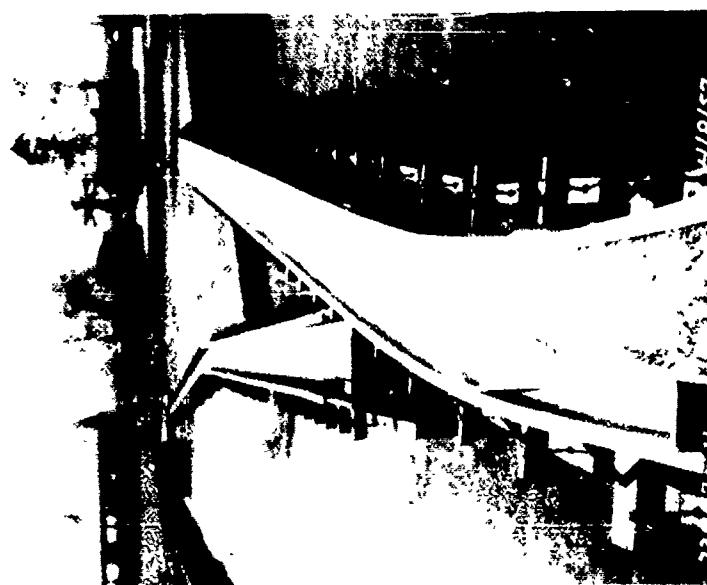


Looking downstream

Photo 30. Alternative design of confluence

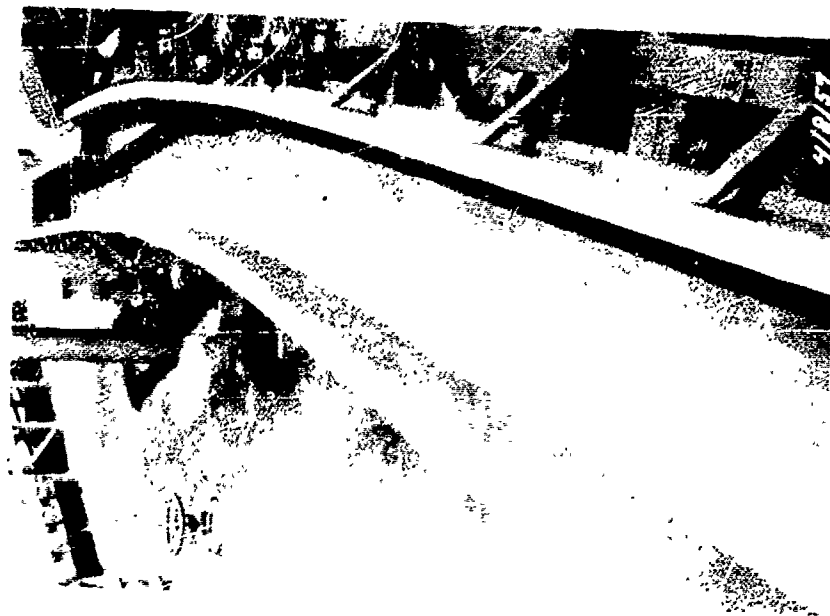


Looking upstream from sta 131+25



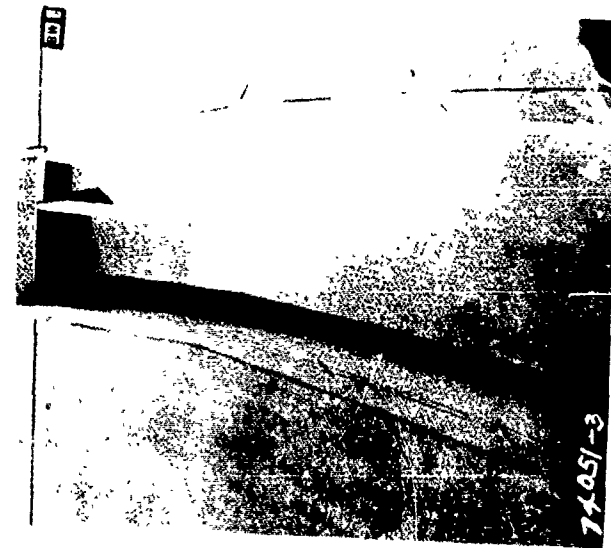
Looking downstream

Photo 31. Alternative design flow conditions;
Burbank-Western 11,000 cfs, Stough Canyon channel 2,000 cfs



General view

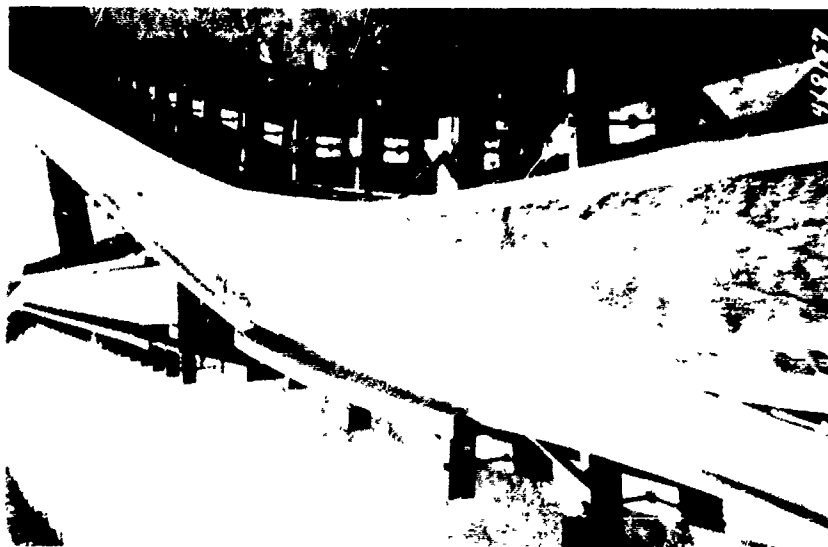
Photo 32. Final design, looking upstream at Burbank-Western - Stough Canyon channel confluence



Closeup view



Looking upstream

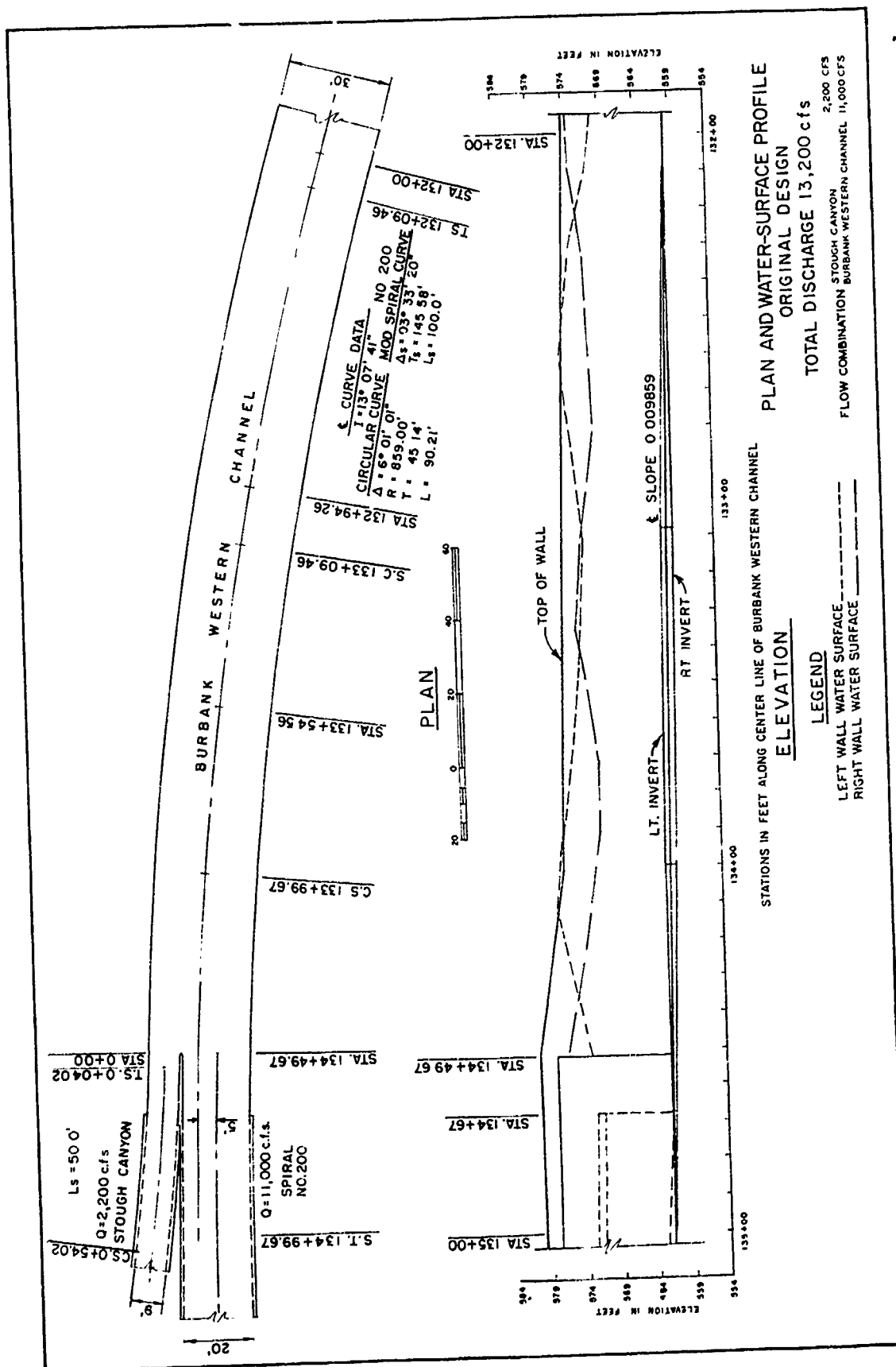


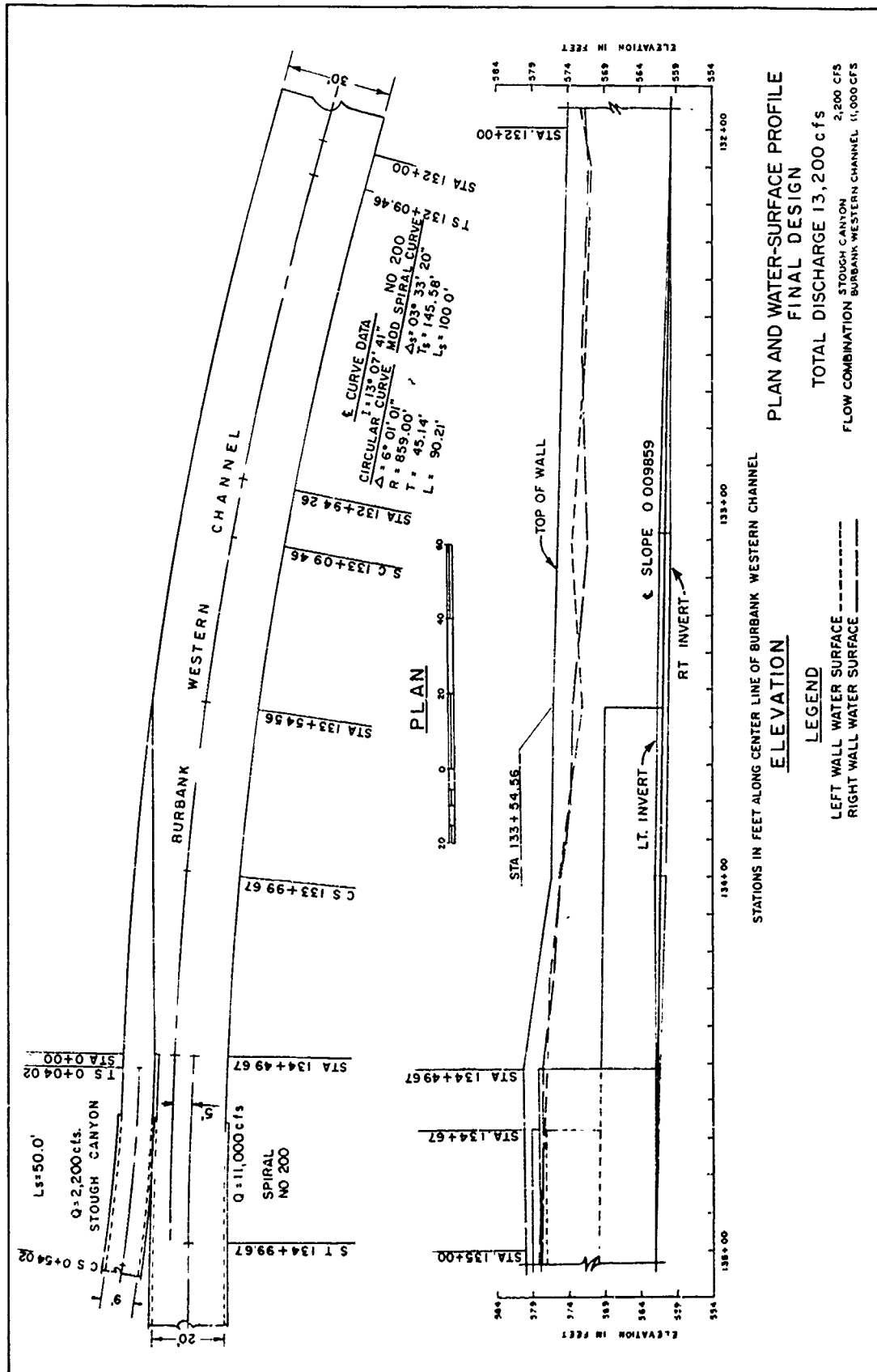
Looking downstream

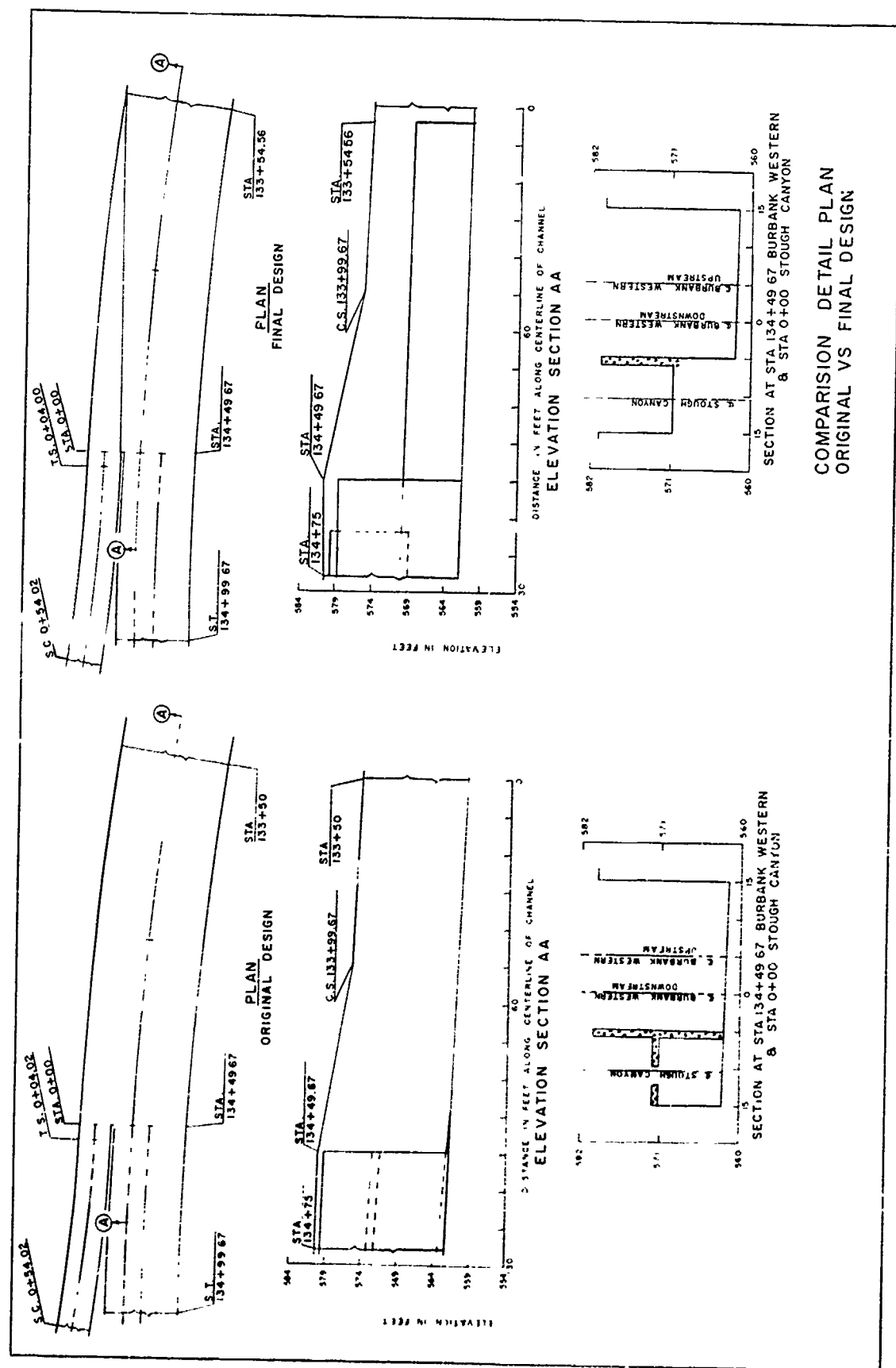


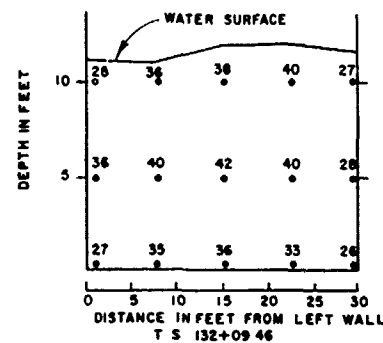
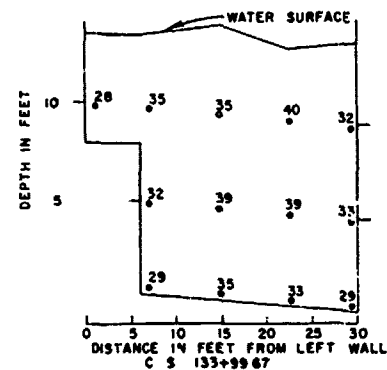
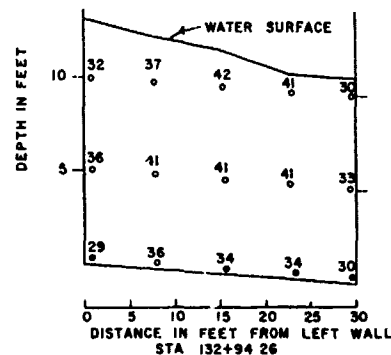
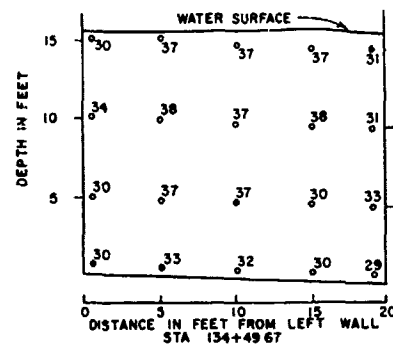
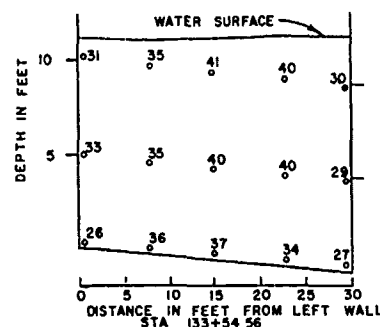
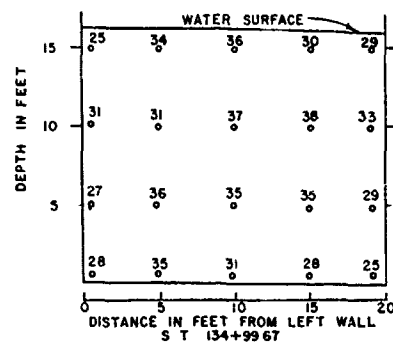
Closeup view, looking upstream

Photo 33. Final design flow conditions;
Burbank-Western channel 11,000 cfs, Stough Canyon channel 2,200 cfs









NOTE VELOCITIES ARE
IN FEET PER SECOND

VELOCITIES

FINAL DESIGN

DISCHARGE (BURBANK-WESTERN) 11,000 CFS
DISCHARGE (STOUGH CANYON) 2,200 CFS

UPPER BURBANK-WESTERN SYSTEM
BURBANK-WESTERN CHANNEL - HANSEN HEIGHTS CHANNEL

The Prototype

(For a description of the prototype, see paragraph 35.)

Original-Final Design

41. The model, built to a scale ratio of 1:24 (Photo 34), reproduced approximately 1300 ft of the Burbank-Western channel and 200 ft of the Hansen Heights channel. In the reach upstream from the junction, the Burbank-Western and Hansen Heights channels have a base width of 20 ft. In the confluence structure, the Burbank-Western channel alignment curved to the right on a radius of 609.48 ft. Downstream from the end of the confluence, the main channel has a constant width of 30 ft.

42. Three discharge combinations were considered pertinent to the design of the confluence: (a) 2100 cfs in Burbank-Western channel and 4100 cfs in Hansen Heights channel, (b) 6500 cfs in Burbank-Western channel and 2000 cfs in Hansen Heights channel, and (c) 6000 cfs in Burbank-Western channel and 2500 cfs in Hansen Heights channel. The maximum depth of flow through the confluence structure will occur when the discharge of 6000 cfs in Burbank-Western channel combines with the discharge of 2500 cfs in Hansen Heights channel (combination (c) above). However, only the water-surface profiles for combinations (a) and (b) were measured and plotted for this report; and only visual observation and photographs (Photo 35) were made of combination (c).

43. With flow combination (a), waves of large magnitude overtopped the channel walls due to the sudden expansion at the confluence. The resulting waves traveled across to strike the left and right walls at intervals, and the waves produced extended for about 350 ft. Water-surface profiles for combination (a) are shown in Plate 22 and flow conditions in Photo 36.

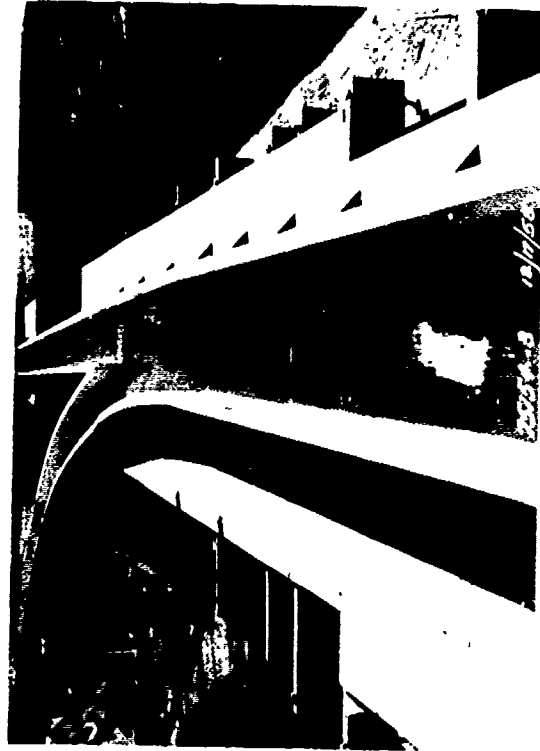
44. Flow combination (b) had the maximum discharge in

Burbank-Western channel (6500 cfs) which, with a simultaneous discharge of 2000 cfs in Hansen Heights channel, produced a hydraulic jump at the end of the Hansen Heights channel. The undulating waves produced by the hydraulic jump extended through the confluence, then diminished rapidly as they traveled downstream. Water-surface profiles are shown in Plate 23 and flow conditions in Photo 37.

45. Results of the tests indicated that, in general, the design of the confluence was satisfactory. No revisions were made to the original design. Therefore, the original design concept was adopted as the final plan.



Looking downstream from centerline
of Burbank-Western channel



Looking upstream from sta 332+00

Photo 34. Final design, Burbank-Western channel - Hansen Heights channel



Looking downstream from the
Hansen Heights channel side



Looking upstream

Photo 35. Final design flow conditions;

Burbank-Western channel 6000 cfs, Hansen Heights channel 2500 cfs



Looking downstream from the Hansen Heights side



Looking downstream from the Burbank-Western side

Photo 36. Final design flow conditions;

Burbank-Western channel 2100 cfs, Hansen Heights channel 4100 cfs

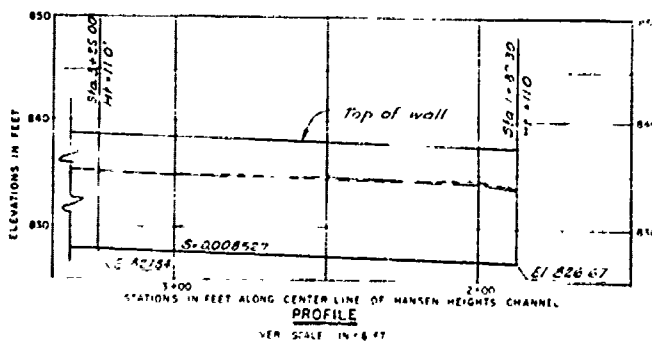
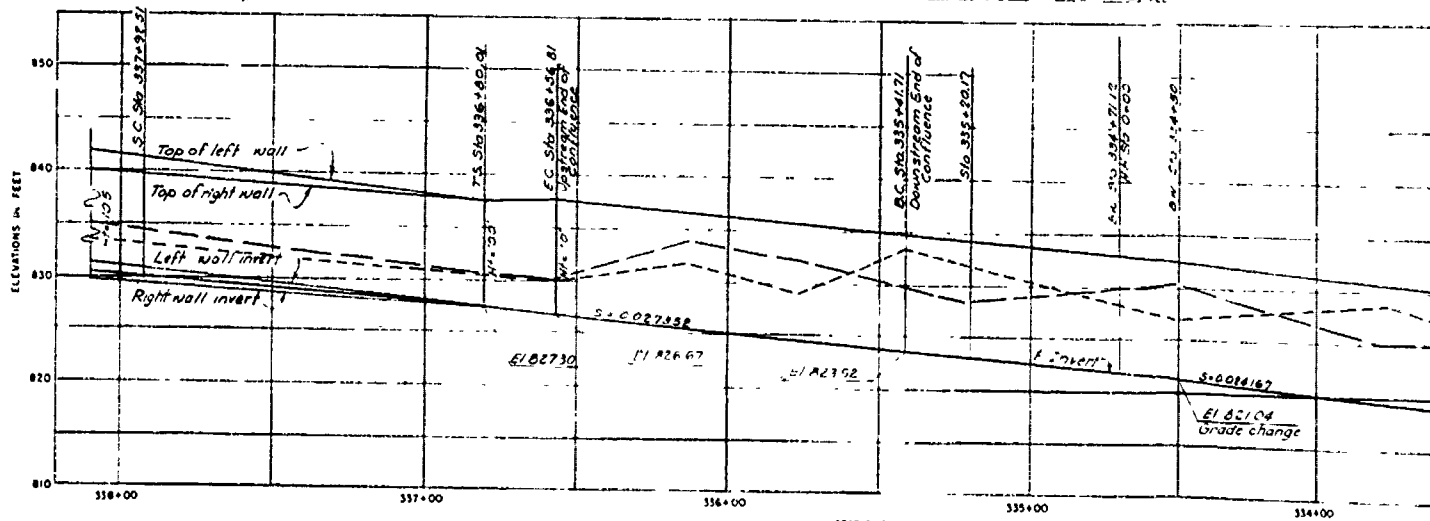
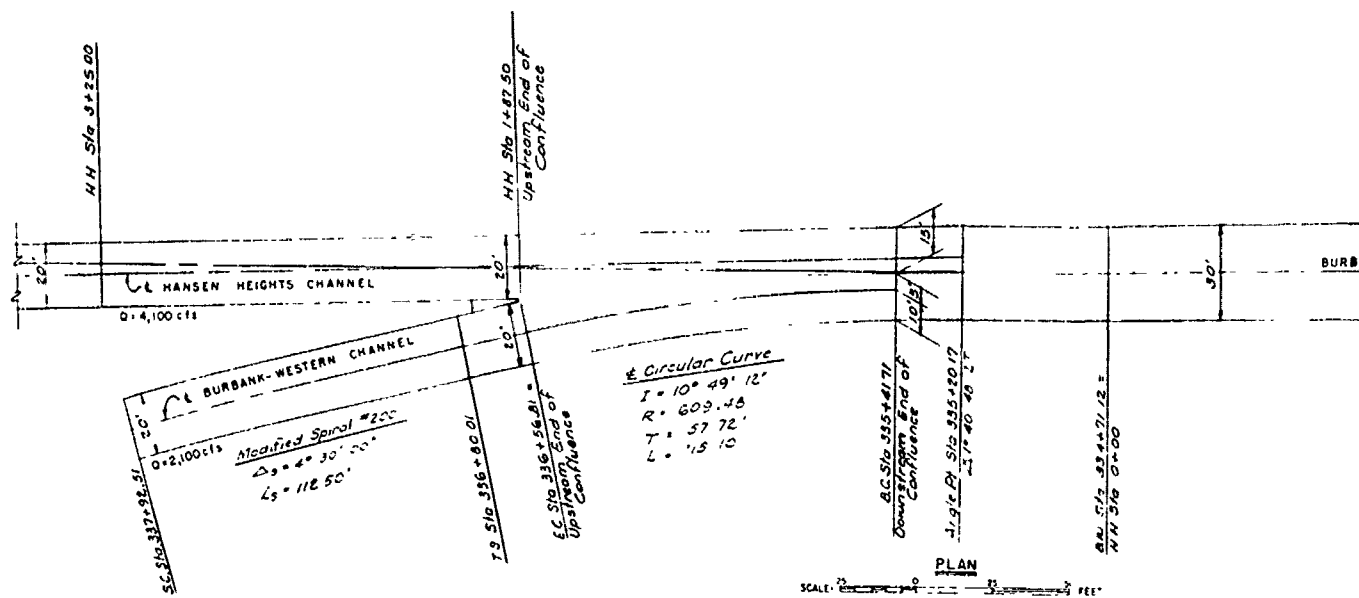


Looking downstream from the Burbank-Western side

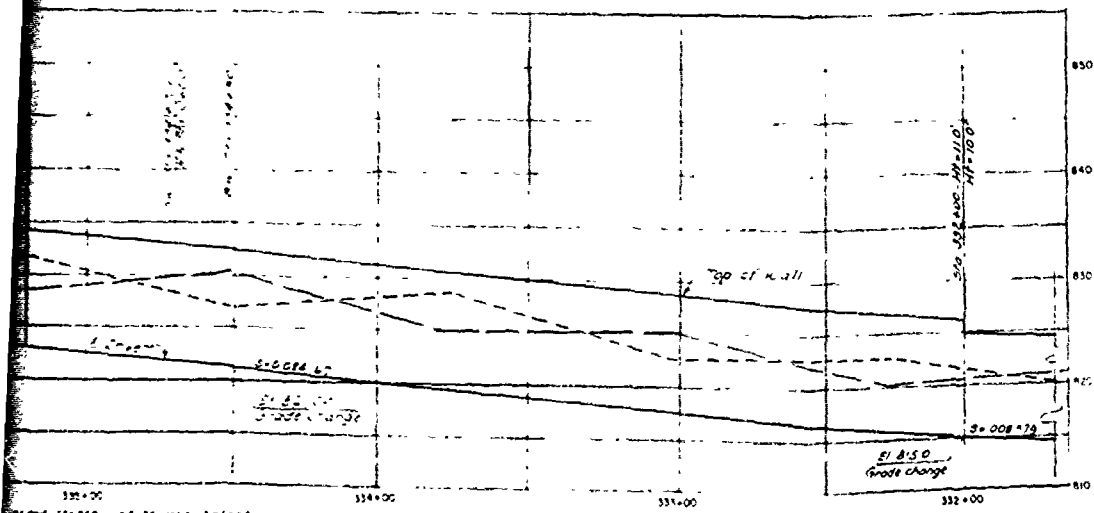
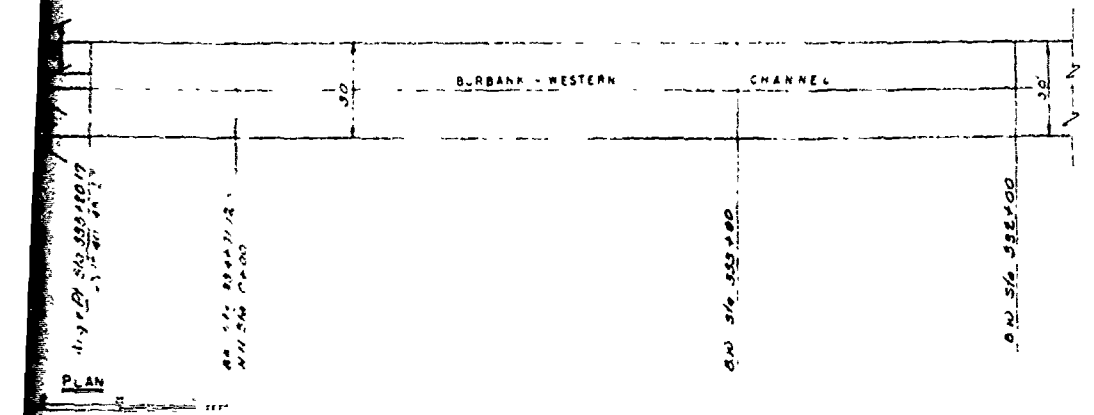
Photo 37. Final design flow conditions;
Burbank-Western channel 6500 cfs, Hansen Heights channel 2000 cfs



Looking upstream

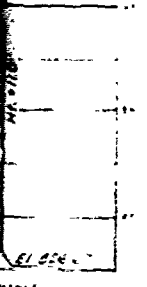


LEFT WALL WATER
RIGHT WALL WATER



ALONG CENTER LINE OF MAIN CHANNEL

VERT SCALE 1" = 5'

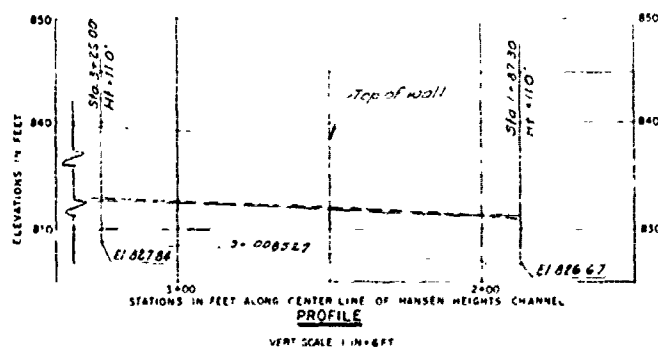
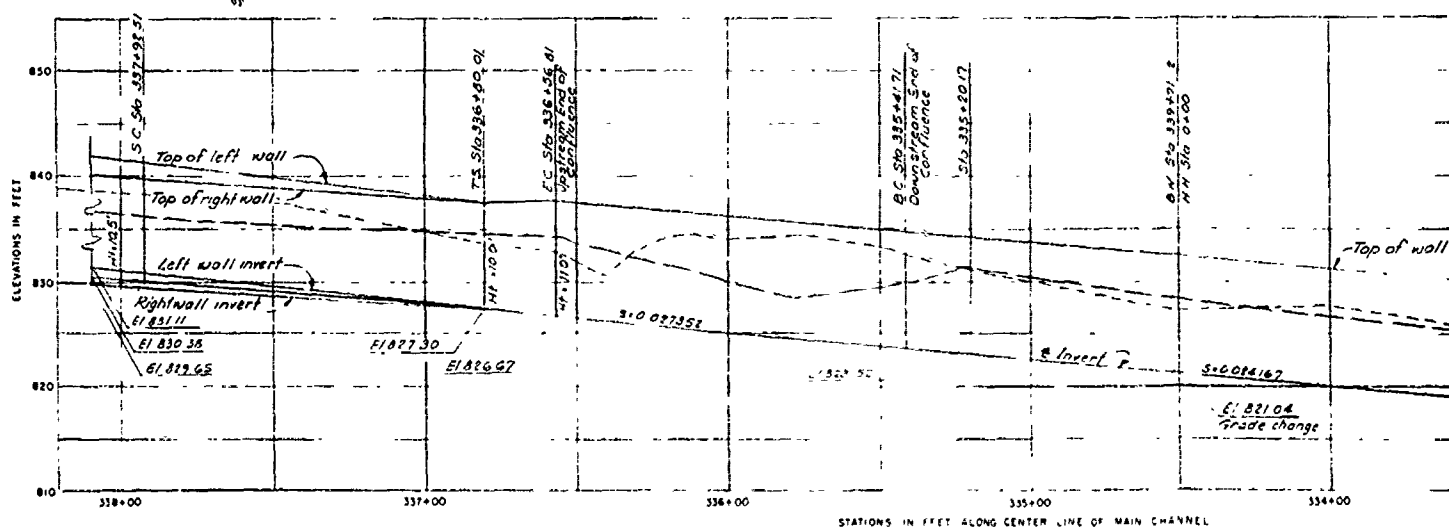
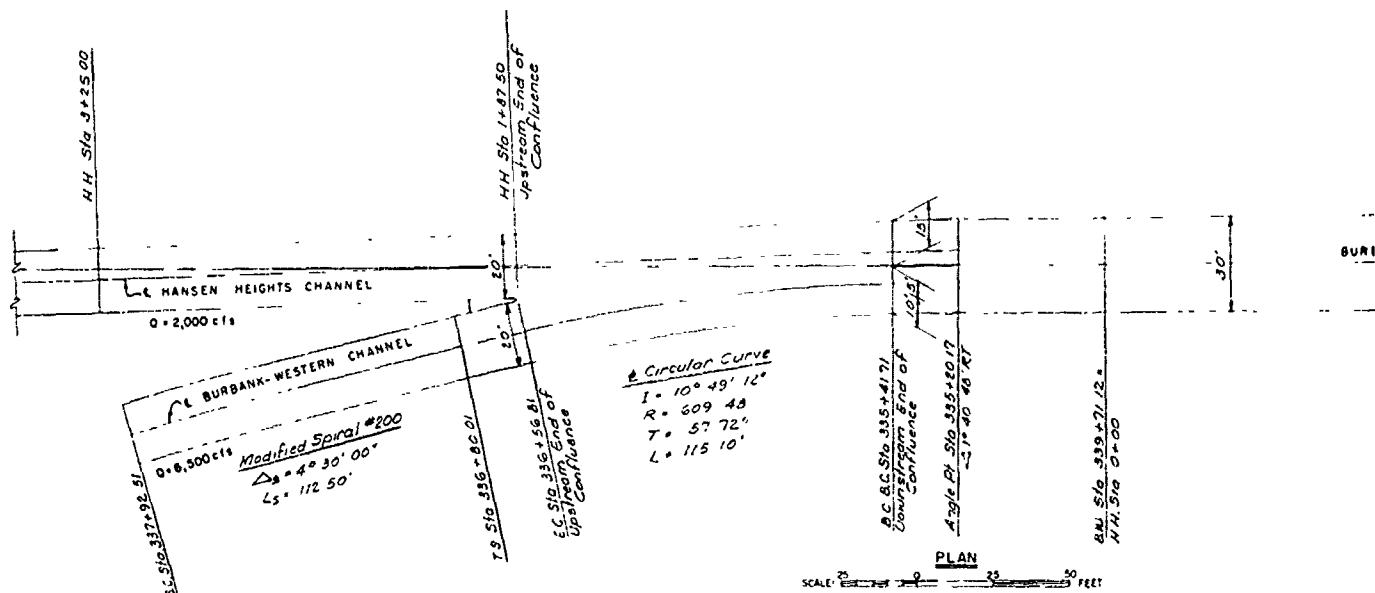


LEGEND

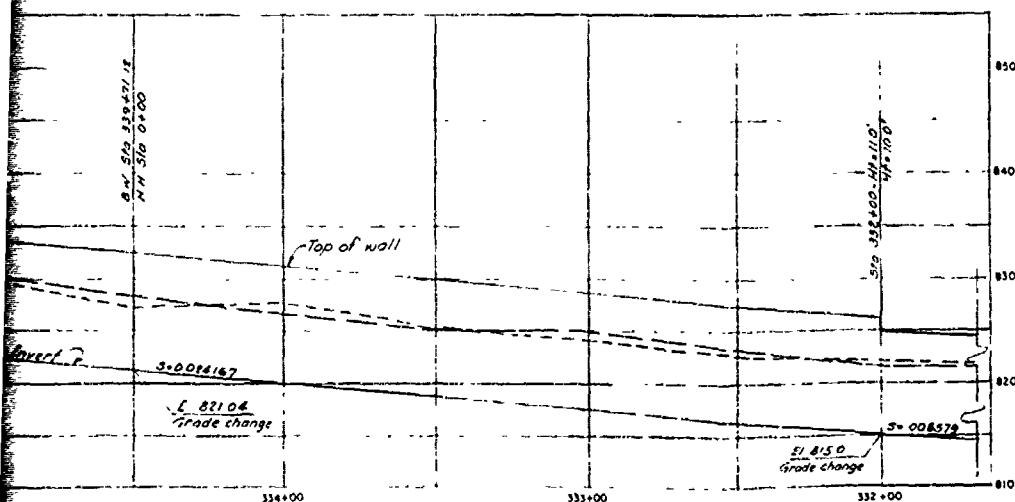
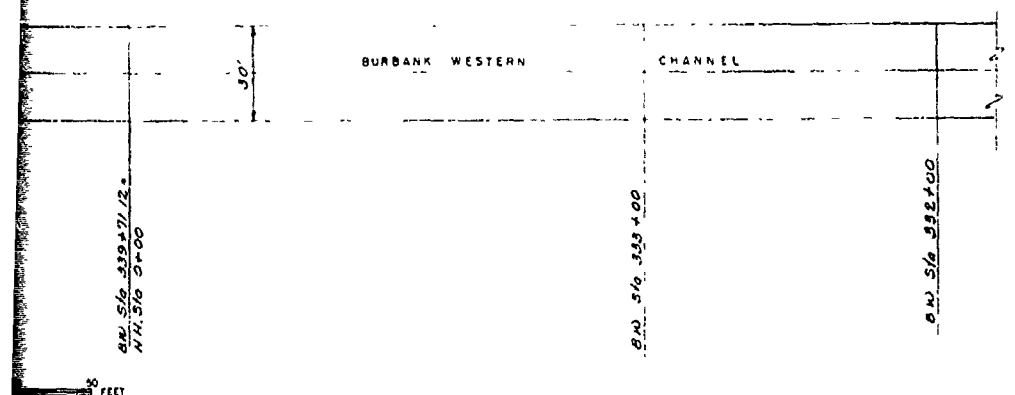
— H.A. WATER SURFACE

--- H.A. WATER SURFACE

MODEL LAYOUT
AND
WATER-SURFACE PROFILES
FINAL DESIGN
TOTAL DISCHARGE 6,200cfs



LEFT WALL WATER
RIGHT WALL WATER



LINE OF MAIN CHANNEL

46 FT

850

840

830

LEGEND
 LEFT WALL WATER SURFACE
 RIGHT WALL WATER SURFACE

**MODEL LAYOUT
 AND
 WATER-SURFACE PROFILES
 FINAL DESIGN
 TOTAL DISCHARGE 8,500cfs**

BALLONA CREEK CHANNEL--BENEDICT CANYON CHANNEL

The Prototype

46. The confluence structure of Ballona Creek channel and Benedict Canyon channel is located about 9 miles west of the city of Los Angeles and just south of the city of Beverly Hills. The cross section of Ballona Creek channel upstream of the confluence consists of an 80-ft-wide reinforced concrete rectangular section, with wall heights of 11.0 ft. Above this section, a 10-ft berm extends back from the channel wall with 1V-on-2H side slopes up to natural ground (composite cross section). This portion of the main channel is designed to carry 36,000 cfs. A warped-wall section between sta 304+00 and E.C. sta 301+46.69 changes the cross section of the main channel from the composite cross section to a trapezoidal cross section having 1V-on-3H side slopes. The warped section was followed by a 2048.72-ft-radius curve that extended to L.C. sta 292+15.

47. Benedict Canyon channel is rectangular in cross section with a base width of 22 ft. The downstream ends of Benedict Canyon channel walls conform to the plane at the right side slope of Ballona Creek channel. Benedict Canyon channel is designed for 12,000 cfs and 40,500 cfs for Ballona Creek channel downstream from the confluence. However, it is unlikely that standard project flood discharge in each channel will occur at the same time. Observations and measurements were then made with: (a) discharge combination of 12,000 cfs in Benedict Canyon channel and 22,000 cfs in Ballona Creek channel, which produced a total flow of 34,000 cfs downstream from the confluence and (b) discharge combination of 4,500 cfs in Benedict Canyon channel and 36,000 cfs in Ballona Creek channel, which produced a total flow of 40,500 cfs downstream from the confluence.

The Model

48. A general model, constructed to an undistorted scale ratio

of 1:40, reproduced 3250 ft of Ballona Creek channel and 700 ft of Benedict Canyon channel. The inside of the model was constructed of plywood and painted with exterior high-gloss enamel. Tests were made to determine the "n" value in the trapezoidal portion of the model, which was built to prototype slope. After several trials to determine the "n" value of the model, the final solution was an average "n" of 0.019 which was approximately the "n" value of the prototype. Strips of screen wire 4 in. wide, used for the final results, were placed near the toe of slope. The "n" value was based on a discharge of 40,500 cfs.

Original-Final Design

49. The confluence structure was first tested with the end of the divider wall at sta 304+00. The final design (Photo 38) altered the confluence by shortening the divider wall by approximately 80 ft. Since the shorter divider wall made appreciable difference in the flow pattern, this plan was recommended for the prototype.

50. With 22,000 cfs in Ballona Creek channel and 12,000 cfs in Benedict Canyon channel, flow conditions at the confluence and in the curve downstream were acceptable (Photo 39). Flow from Benedict Canyon channel entered the Ballona Creek channel smoothly, with the exception of a small wave that was created on the left side of Ballona Creek within the warped transition section and extended downstream for just a short distance. The water-surface profiles for this combination are shown in Plate 24.

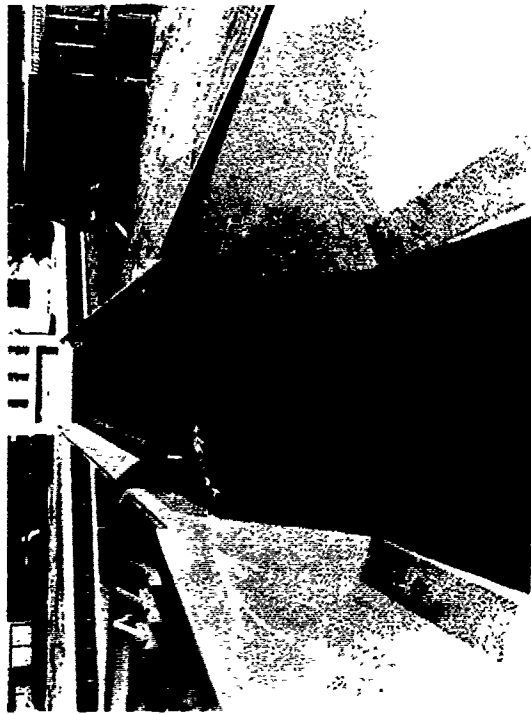
51. The simultaneous flows of 36,000 cfs in Ballona Creek channel and 4500 cfs in Benedict Canyon channel produced the greatest depth downstream from the confluence. At the design discharge of 40,500 cfs, the water surface was reasonably smooth and water depths were fairly uniform except at the start of the circular curve where high and low water depths occurred on the levee slopes. In the curved reach of Ballona Creek channel downstream from the confluence, no unsatisfactory waves or flow conditions developed. Water-surface profiles along the

left and right walls are shown in Plate 25; Photo 40 shows flow conditions for these flows.



Looking downstream from centerline of
Ballona Creek channel

Photo 38. Final design, Ballona Creek channel-Benedict Canyon channel

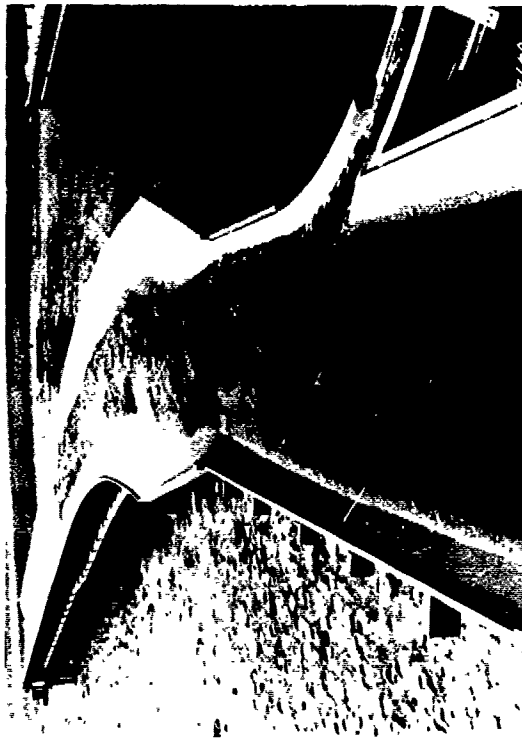


Upstream view of confluence
from sta 298+00



Looking downstream from right side of
Ballona Creek, sta 311+00

Photo 39. Final design flow conditions; Ballona Creek channel 22,000 cfs, Benedict Canyon channel 12,000 cfs



Looking downstream from centerline of
Ballona Creek, sta 310+00



Looking downstream from right side of
Ballona Creek, sta 310+00

Photo 40. Final design flow conditions;
Ballona Creek channel 36,000 cfs, Benedict Canyon channel 4,500 cfs

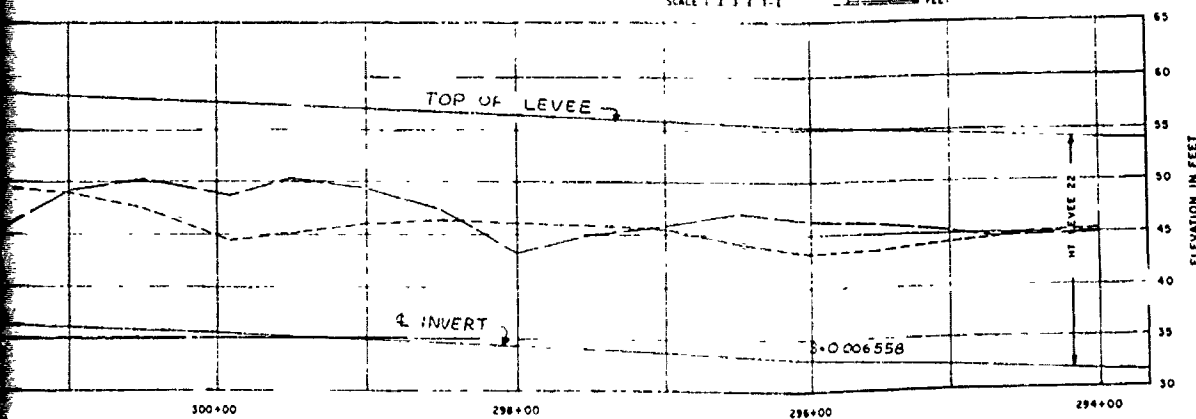


Looking downstream from centerline of
Ballona Creek, sta 310+00

Δ - 26° 03' 23"
R - 2048 72'
T - 474 05'
L - 931 69



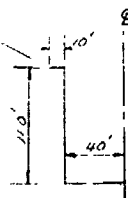
SCALE 90 0 90 100 FEET



IN FEET ALONG CENTER LINE OF MAIN CHANNEL.

PROFILE

VERT SCALE IN = 5' T



SECTION A-A

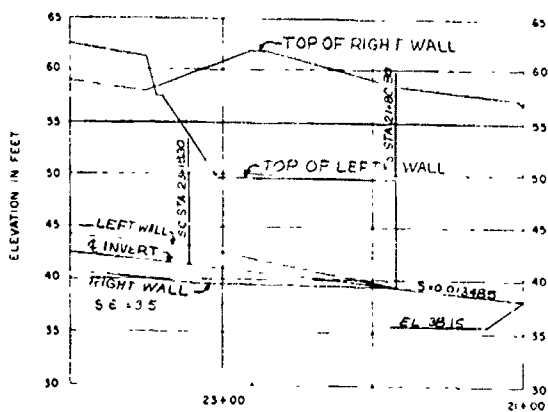
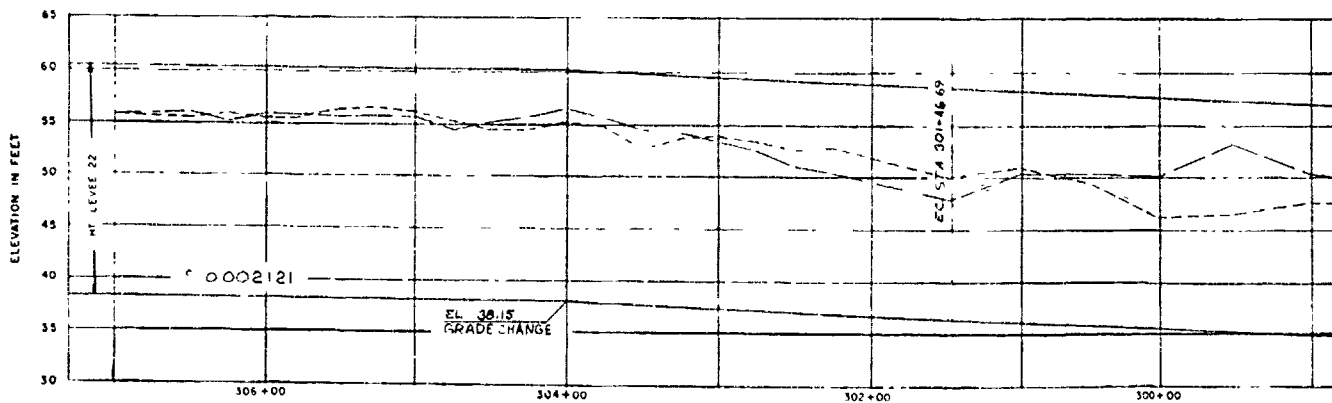
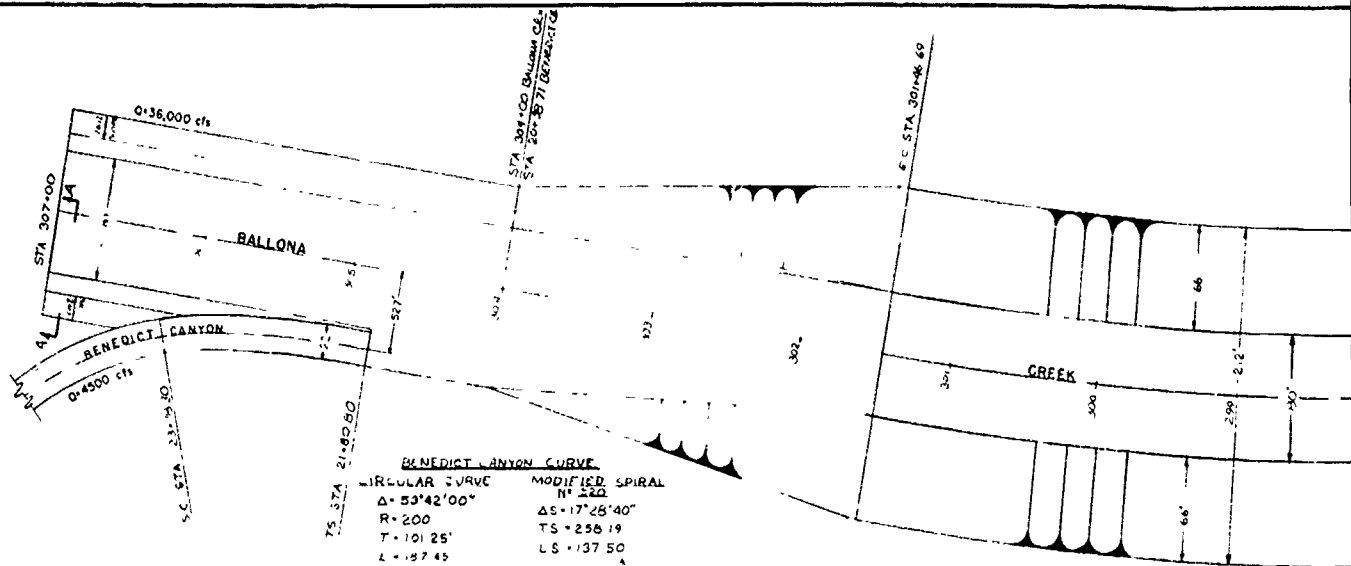
NOT TO SCALE

LEGEND

LEFT WALL WATER SURFACE _____
RIGHT WALL WATER SURFACE _____

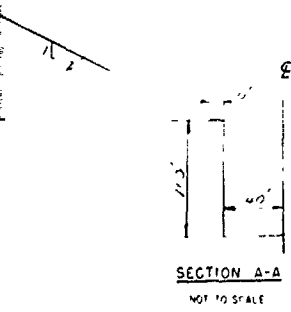
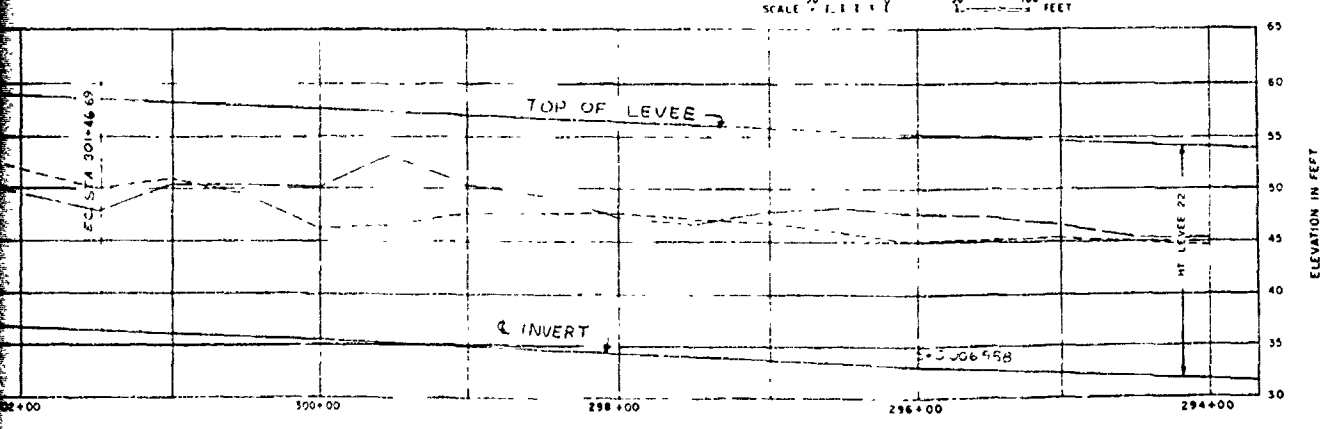
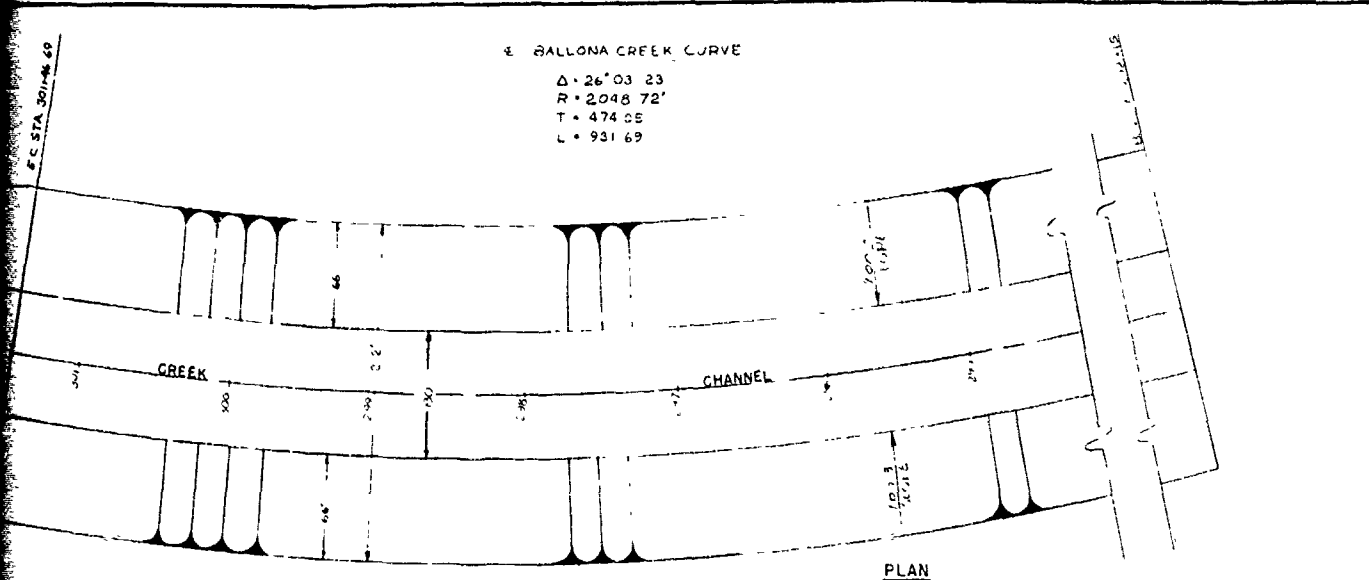
MODEL LAYOUT
AND
WATER-SURFACE PROFILES
FINAL DESIGN
TOTAL DISCHARGE 34,000cfs

2



STATIONS IN FEET ALONG CENTER LINE OF BENEDICT CANYON
PROFILE

LEFT
RIGHT



LEGEND

LEFT WALL WATER SURFACE

RIGHT WALL WATER SURFACE

MODEL LAYOUT
AND
WATER-SURFACE PROFILES
FINAL DESIGN
TOTAL DISCHARGE 40,500cfs

BENEDICT CANYON CHANNEL - REXFORD-MONTE MAR CHANNEL

The Model

52. The model, built to a scale ratio of 1:24, simulated about 2400 ft of Benedict Canyon channel and 600 ft of Rexford-Monte Mar channel (Photo 41). The inlet for the Rexford-Monte Mar channel is aligned so that the flow from the drain will be parallel with the flow in Benedict Canyon channel. The width of the main channel at the junction is 34.5 ft. The left wall converges from this width toward the channel centerline to a width of 26 ft at sta 166+50; the left wall again converges at a rate of 1 ft in 150 ft to a width of 24 ft at sta 163+50.

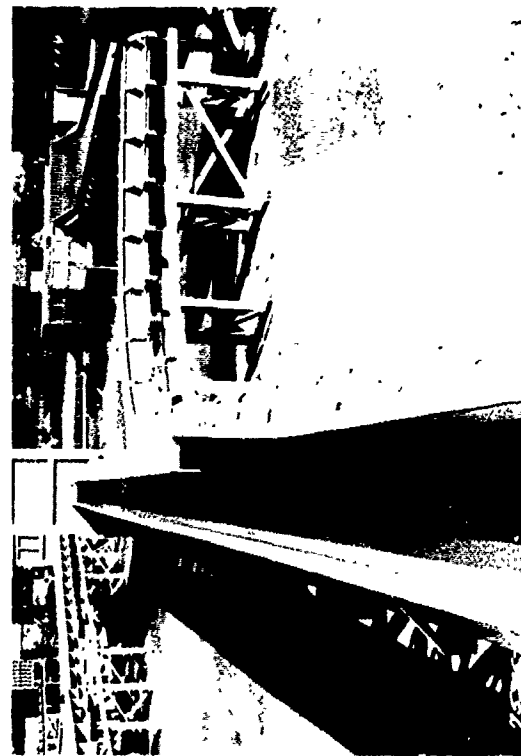
Final Design

53. Tests with the discharge combination of 11,000 cfs in Benedict Canyon channel and 1000 cfs in Rexford-Monte Mar channel showed the formation of waves downstream from the junction (Photo 42); however, these waves did not overtop the design walls downstream from the confluence. Improvement in flow conditions was noted (Photo 43) with the discharge combination of 10,100 cfs in Benedict Canyon channel and 1900 cfs in Rexford-Monte Mar channel. Results of the tests indicated that the design of the confluence was generally satisfactory. Water-surface profiles for these tests are shown in Plates 26 and 27; velocity distribution cross sections for the two combinations are shown in Plates 28 and 29.



Looking downstream from centerline of
Benedict Canyon channel, sta 175+00

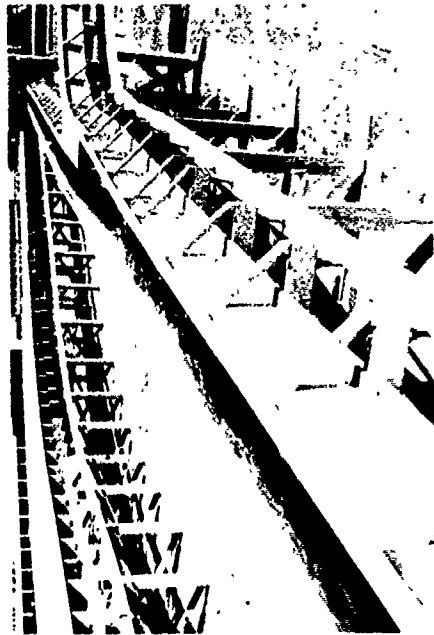
Photo 41. Final design, Benedict Canyon channel - Rexford-Monte Mar channel



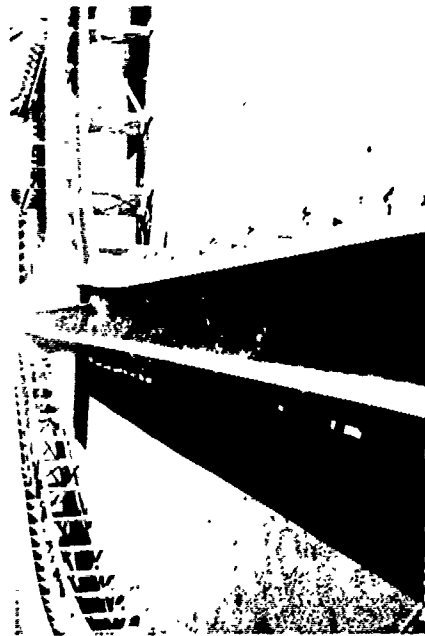
Looking upstream from sta 164+00



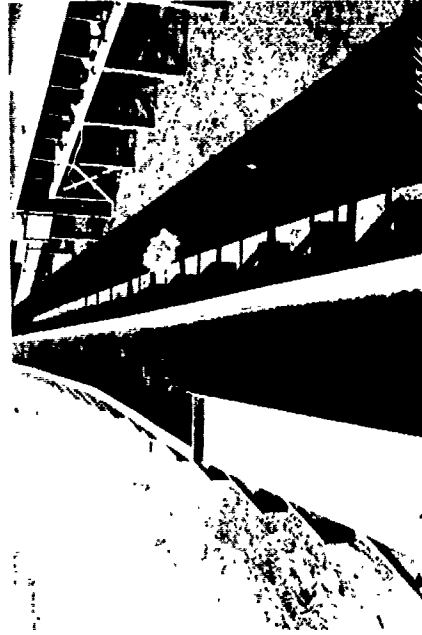
Looking downstream from right side of
Benedict Canyon channel, sta 170+00



Upstream view showing flow along right wall, from
left side of Benedict Canyon channel, sta 163+50



Looking upstream from sta 162+50

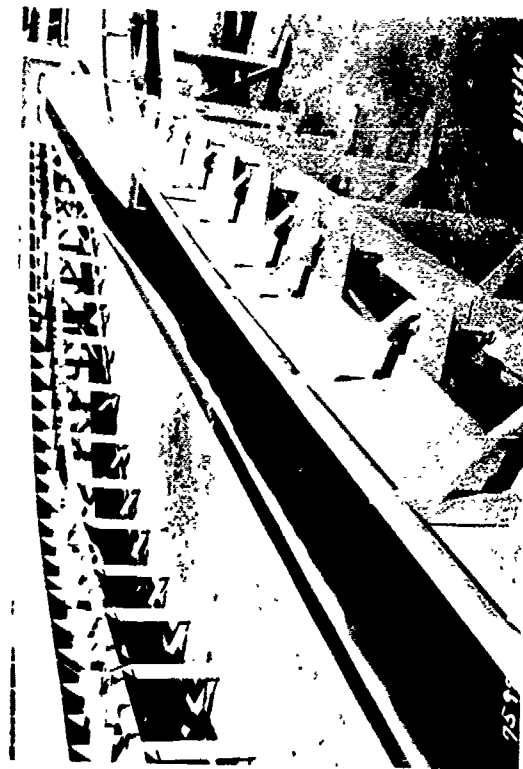


Looking downstream from centerline of
Benedict Canyon channel, sta 170+50

Photo 42. Final design flow conditions; Benedict Canyon channel 11,000 cfs, Rexford-Monte Mar channel 1,000 cfs

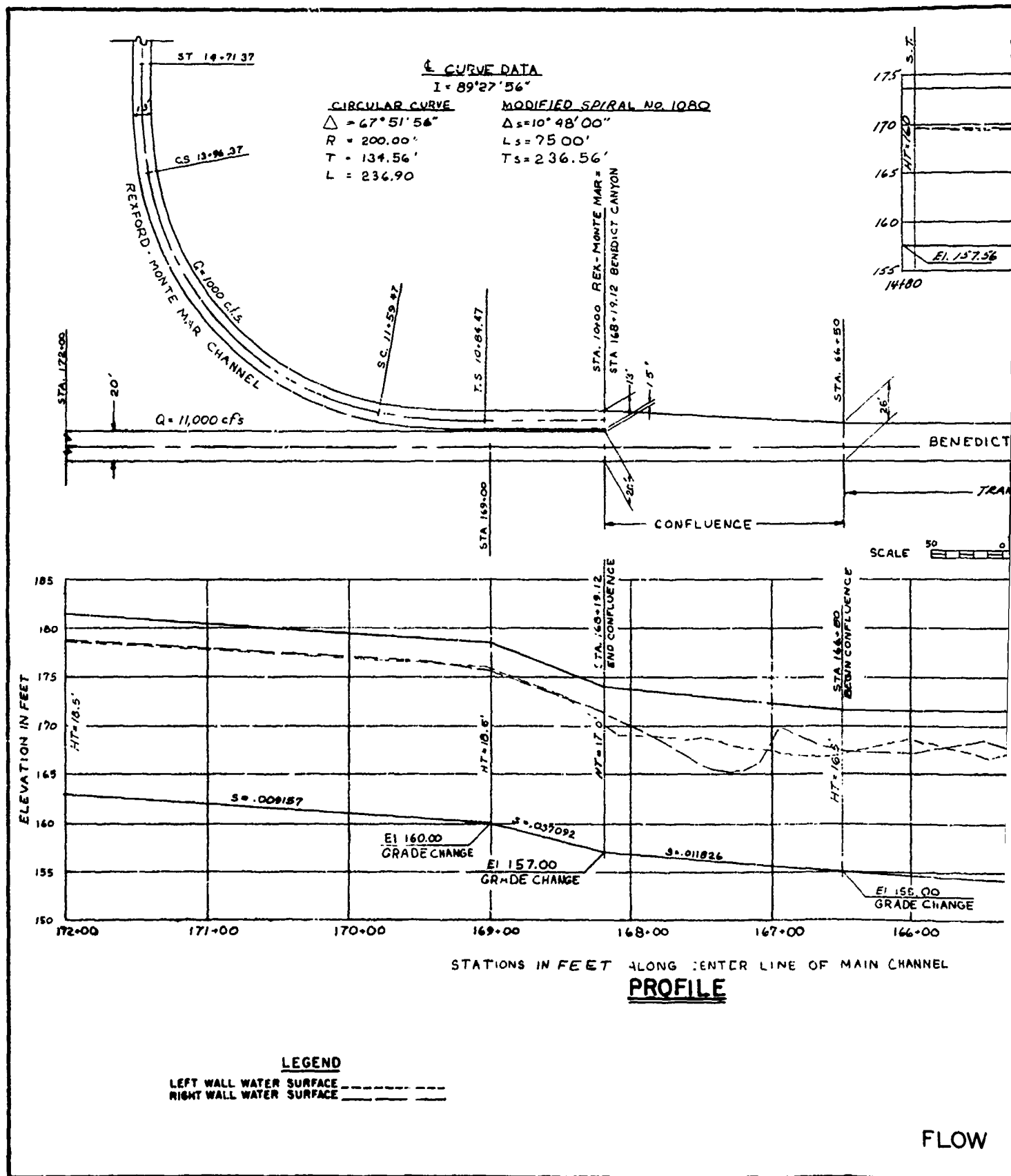


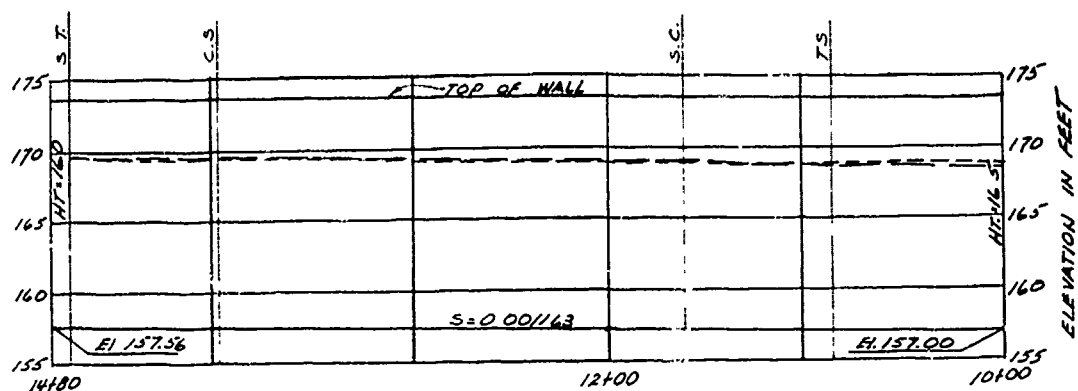
Looking downstream from right side of
Benedict Canyon channel, sta 170+00



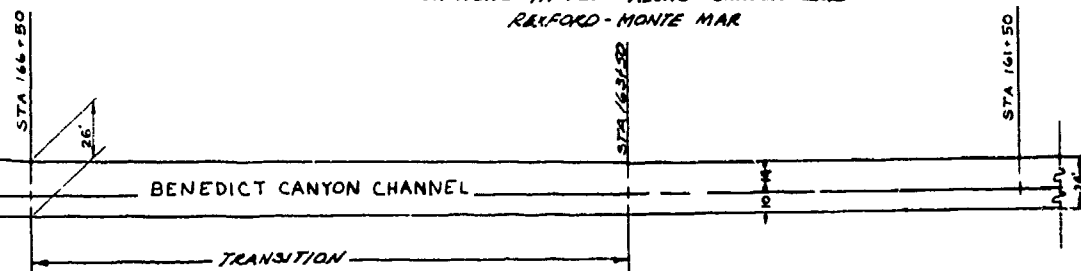
Upstream view showing flow along right wall, from
left side of Benedict Canyon channel, sta 163+50

Photo 43. Final design flow conditions;
Benedict Canyon channel 10,100 cfs, Rexford-Monte Mar channel 1,900 cfs



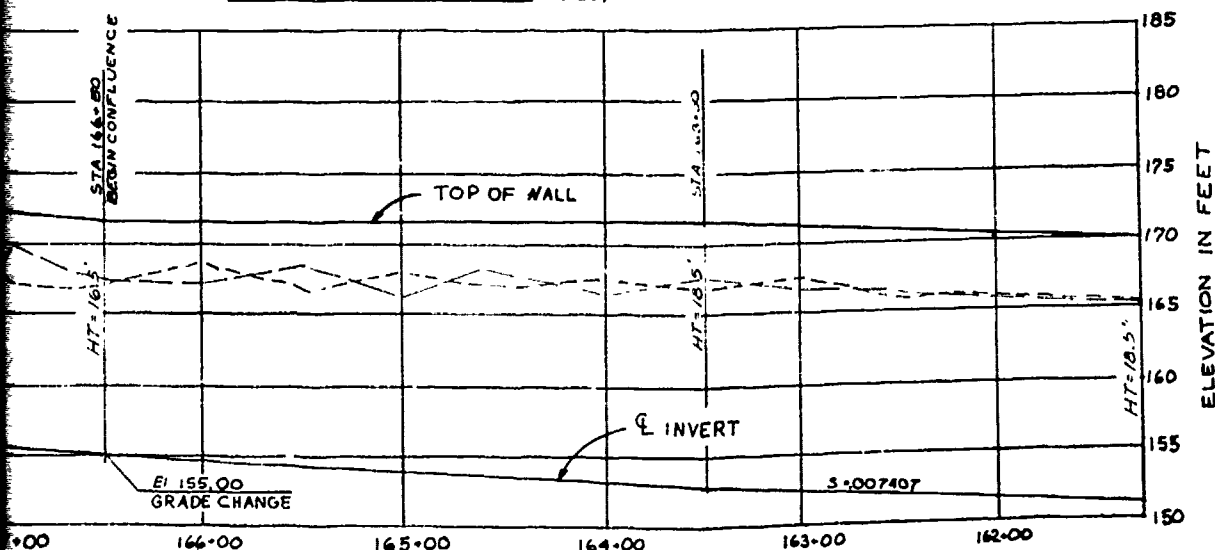


STATIONS IN FEET ALONG CENTER LINE OF
REXFORD-MONTE MAR



PLAN

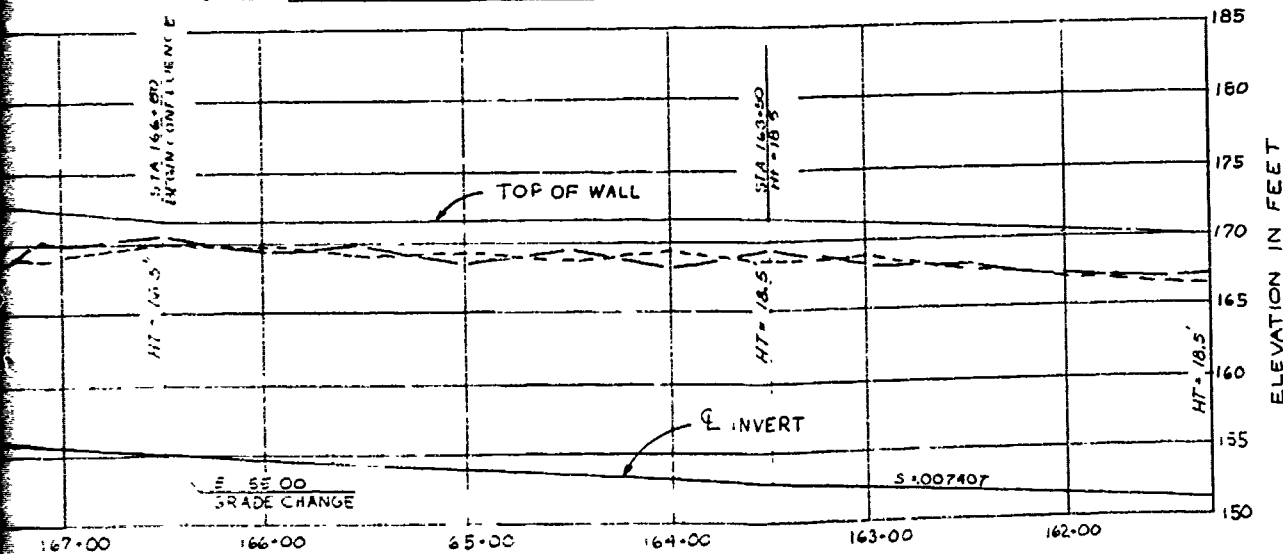
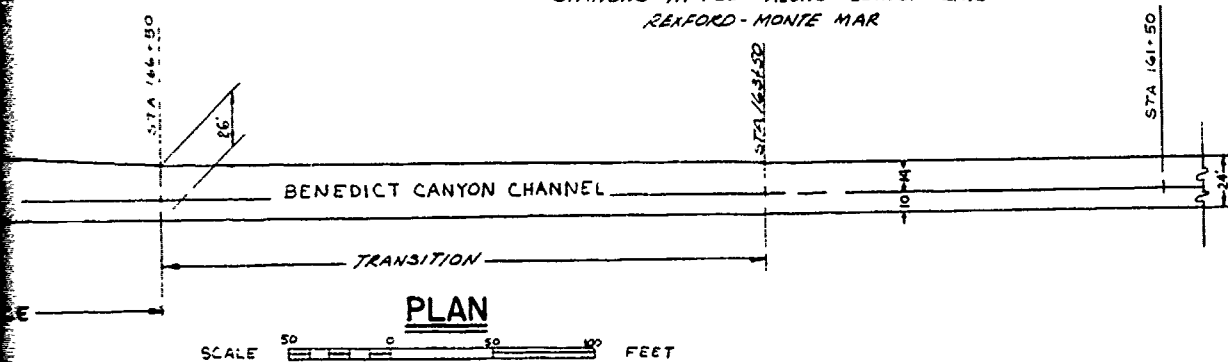
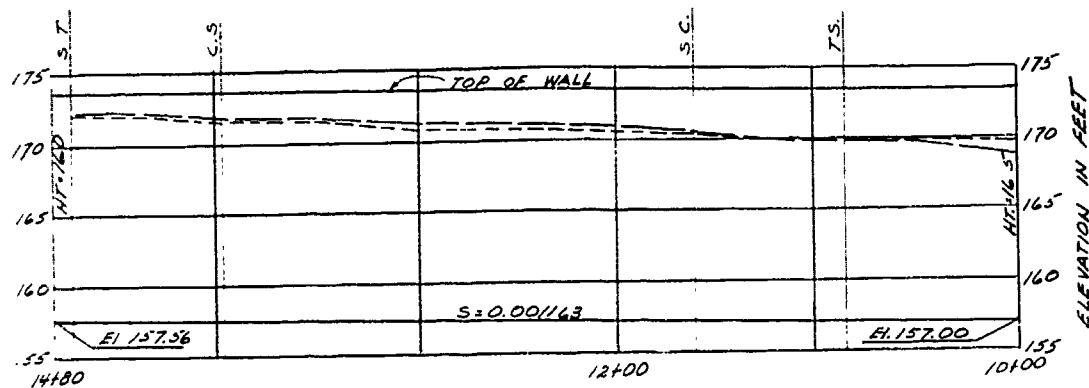
SCALE 50 0 50 100 FEET



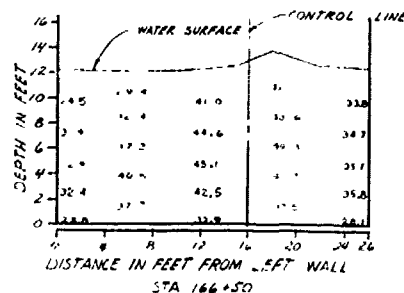
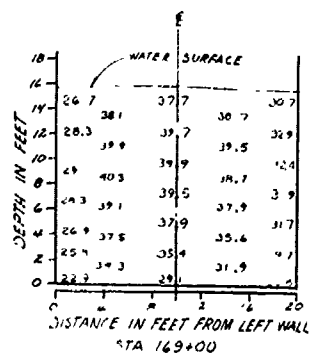
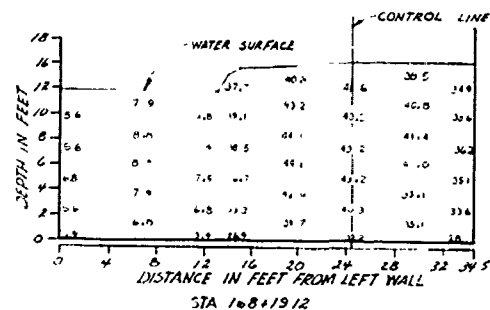
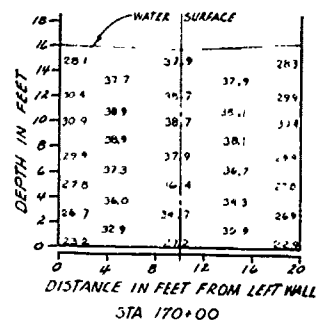
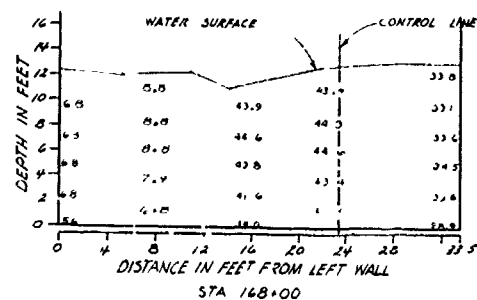
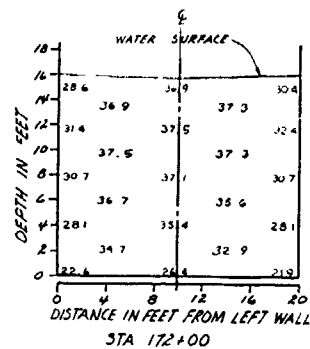
MODEL LAYOUT AND WATER-SURFACE PROFILES FINAL DESIGN

TOTAL DISCHARGE 12,000cfs

FLOW COMBINATION REXFORD-MONTE MAR CHANNEL 1,000 CFS
BENEDICT CANYON CHANNEL 11,000 CFS

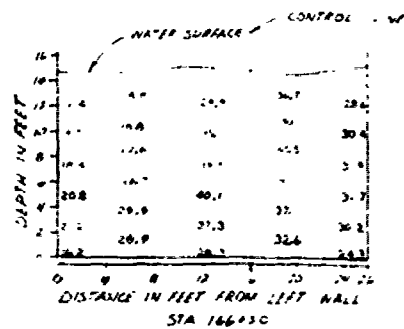
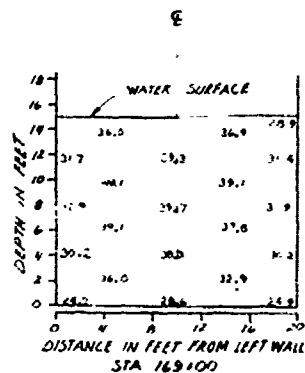
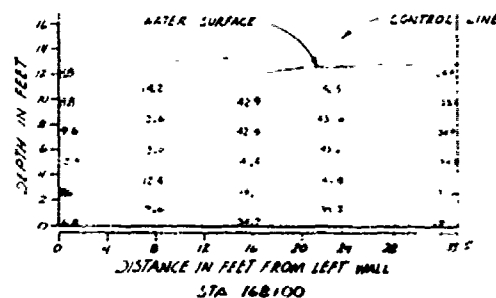
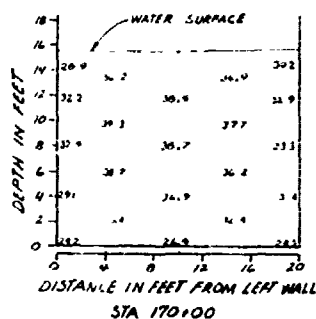
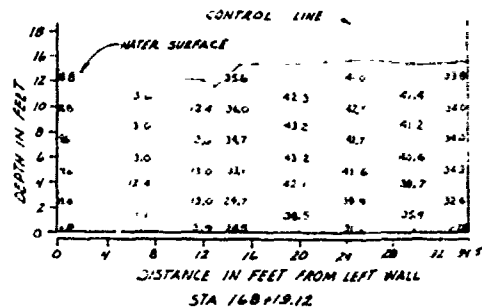
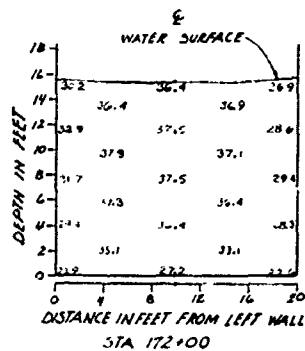


TOTAL DISCHARGE 12,000 cfs
FLOW COMBINATION REXFORD-MONTE MAR CHANNEL 1,900 CFS
BENEDICT CANYON CHANNEL 10,100 CFS

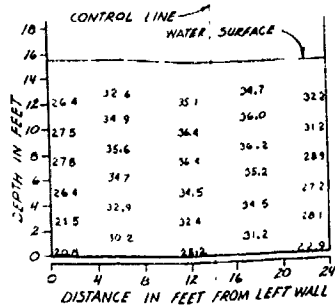
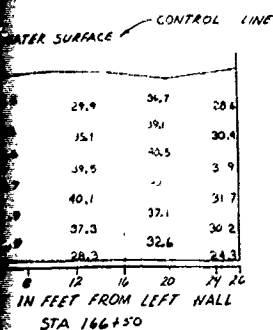
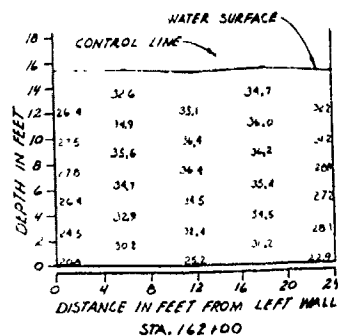
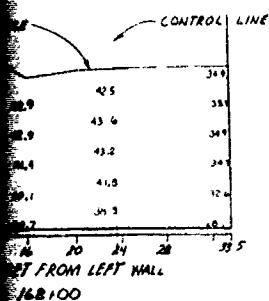
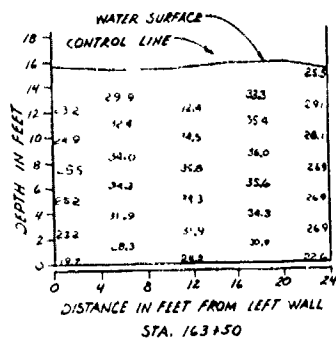
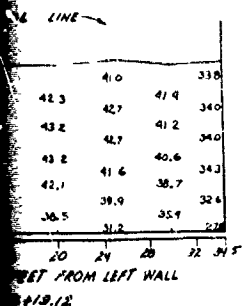


NOTE

ALL SECTIONS SHOWN LOOKING E
VELOCITIES ARE IN FEET PER SEC



ALL SECTIONS SHOWN LOCATING DATA
MEASUREMENTS ARE IN FEET PER SECTION



NOTE:

ALL SECTIONS SHOWN LOOKING DOWNSTREAM
VELOCITIES ARE IN FEET PER SECOND.

VELOCITY DISTRIBUTION
FINAL DESIGN
TOTAL DISCHARGE 12,000cfs
FLOW COMBINATION: BENEDICT CANYON
REXFORD-MONTE MAR

10,100 cfs
1,900 cfs

SAN ANTONIO CHANNEL-CHINO CREEK CHANNEL

Original Design

54. The model, as shown in Plate 30 and Photo 44, was constructed to an undistorted scale ratio of 1:40. Construction of the main channel (San Antonio channel) started at sta 564+00 and extended downstream to sta 540+00. The reach of the main channel upstream from sta 556+95.85 was rectangular in cross section. The confluence structure was located between sta 559+58.59 and sta 557+95.85. A "composite type" transition 90 ft in length joined the rectangular section to the trapezoidal section. The upstream end of the transition (rectangular in cross sections) was at sta 556+95.85 and the downstream end of the transition (trapezoidal in cross section) was at sta 556+05.85. The 60-ft base width and the trapezoidal cross section, with 1V-on-2.25H side slopes, were typical for the main channel downstream from sta 556+05.85. The design of Chino Creek channel consisted of a rectangular channel with a base width of 30 ft. This channel enters the right wall of San Antonio channel on a 601.55-ft-radius curve.

55. This design was tested with a discharge combination of 10,300 cfs in the San Antonio channel and 6700 cfs in the Chino Creek channel. Flow conditions were unsatisfactory in the main channel downstream from the confluence as a result of the wave action set up by the turbulence in the confluence structure. This wave formation created large waves in the trapezoidal channel which were considered objectionable; flow was stable and smooth in the Chino Creek channel. Water-surface profiles are shown in Plate 30 and flow conditions in Photo 45. Tests of the original confluence design indicated that flow conditions could be improved.

Alternative Design

56. This design was similar to the original design except for the confluence structure which was moved downstream between sta 559+30.02

and sta 556+95.85 and for Chino Creek channel which was narrowed from 30 to 25 ft. The main channel at the junctions was 30 ft wide at sta 559+30.02 and 60 ft wide at sta 556+95.85. No changes were made to the trapezoidal channel. Details of the alternative design are shown in Plate 31 and Photo 46.

57. Results of the tests indicated that the design of the confluence structure was unsatisfactory. Although some improvement in flow conditions was accomplished by this design, the flow entering the main channel from Chino Creek caused transverse waves identical with those observed in the original design. These waves originating at the junctions continued downstream into the trapezoidal channel (Photo 47). Water-surface profiles and velocity distribution data for the combination of 10,300 cfs in San Antonio channel and 6700 cfs in Chino Creek are shown in Plates 31 and 32, respectively.

Final Design

58. The unsatisfactory conditions observed during the tests of the alternative design indicated that several modifications and revisions would be required in order to obtain a satisfactory design of the San Antonio-Chino Creek confluence. Photo 48 and Plate 33 show the final confluence design. Chino Creek channel with a 22-ft base width was aligned with spiral transition curves on each end of a 600-ft-radius curve. The length of the spirals was 100 ft and the length of the circular curve was 317.18 ft with a central angle of $30^{\circ}17'19''$. The total deflection angle was $40^{\circ}14'39''$. The superelevation of the invert was held constant (1.14 ft) between C.S. sta 4+17.18 and S.C. sta 1+00.00 and tapered to 0.0 ft at S.T. sta 5+17.18 and T.S. sta 0+00. The confluence structure was 400 ft long and the width at the junction was 53 ft; the width of the downstream end of the confluence was 60 ft. The "composite" transition was lengthened to 125 ft and moved downstream between sta 552+00 and 550+75 to provide a longer reach of straight rectangular channel upstream, effecting more uniform distribution of flow at the beginning of the trapezoidal channel.

59. Complete test data procured with this design indicated that the desired effects had been obtained. The transverse wave action noted in the original and alternative designs was reduced and overall flow conditions were improved. The water surface was reasonably smooth and depths were fairly uniform (Photo 49). Water-surface profiles and velocity distribution cross sections are shown in Plates 33 and 34.



Looking downstream from sta 4+00,
Chino Creek channel



Looking downstream from centerline of
San Antonio channel

Photo 44. Original design, San Antonio channel-Chino Creek channel



Looking downstream from centerline of San Antonio channel



Looking upstream

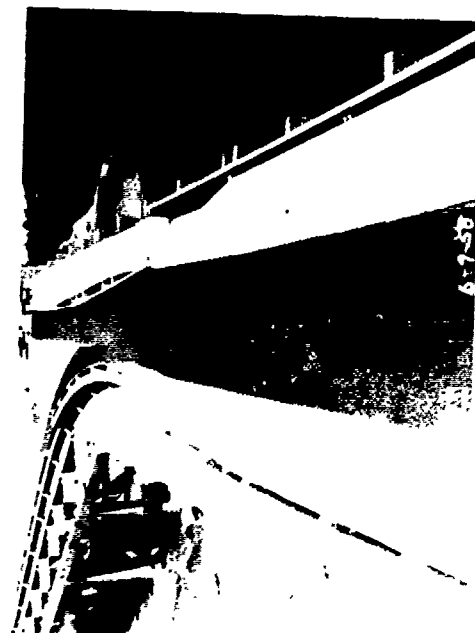


Looking downstream from sta 4+00, Chino Creek channel

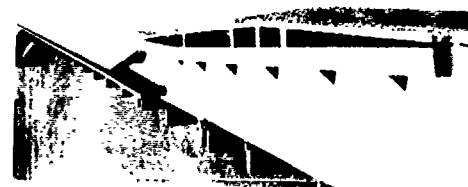
Photo 45. Original design flow conditions; San Antonio channel 10,300 cfs, Chino Creek channel 6,700 cfs



Looking downstream from sta 4+00, Chino Creek channel



Locking upstream



Looking downstream

Photo 46. Alternative design



Looking downstream from centerline of San Antonio channel

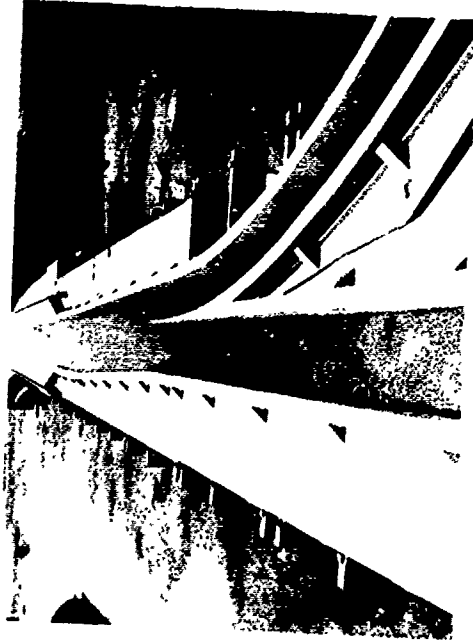


Looking downstream from sta 4+00, Chino Creek channel



Looking upstream from sta 552+00

Photo 47. Alternative design flow conditions; San Antonio channel 10,300 cfs, Chino Creek channel 6,700 cfs



Looking downstream from centerline of San Antonio channel



Looking downstream from Chino Creek channel

Photo 48. Final design, San Antonio channel-Chino Creek channel



Looking upstream from sta 546+00



Looking downstream



Looking downstream from centerline of Chino Creek



Looking upstream from sta 554+00

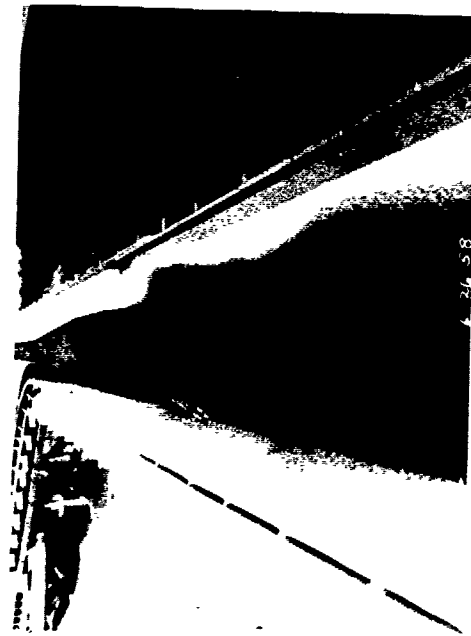
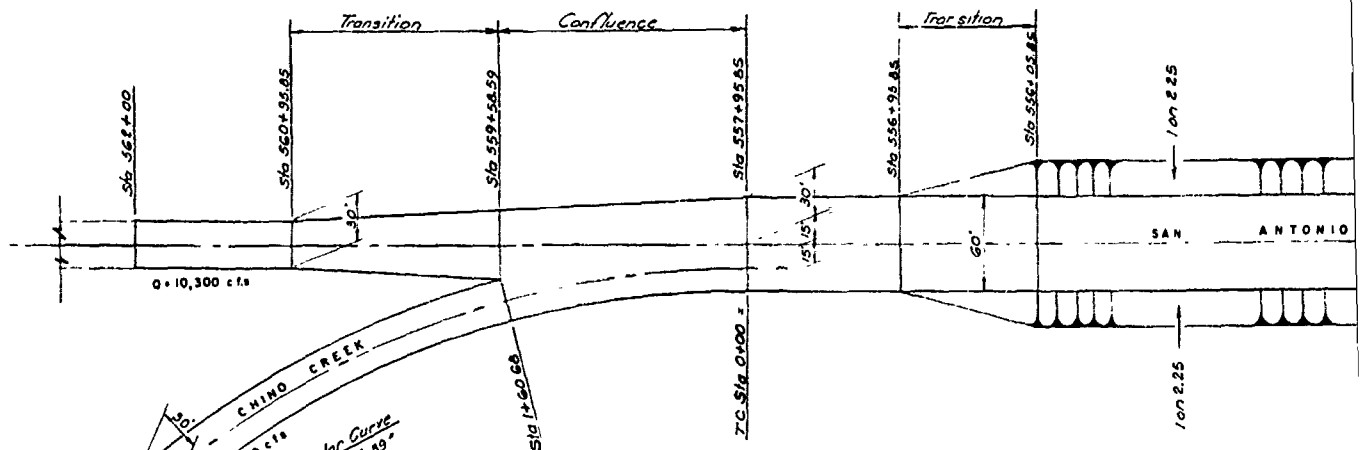
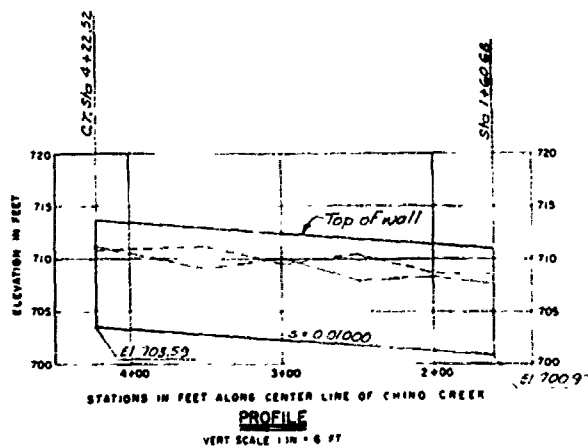
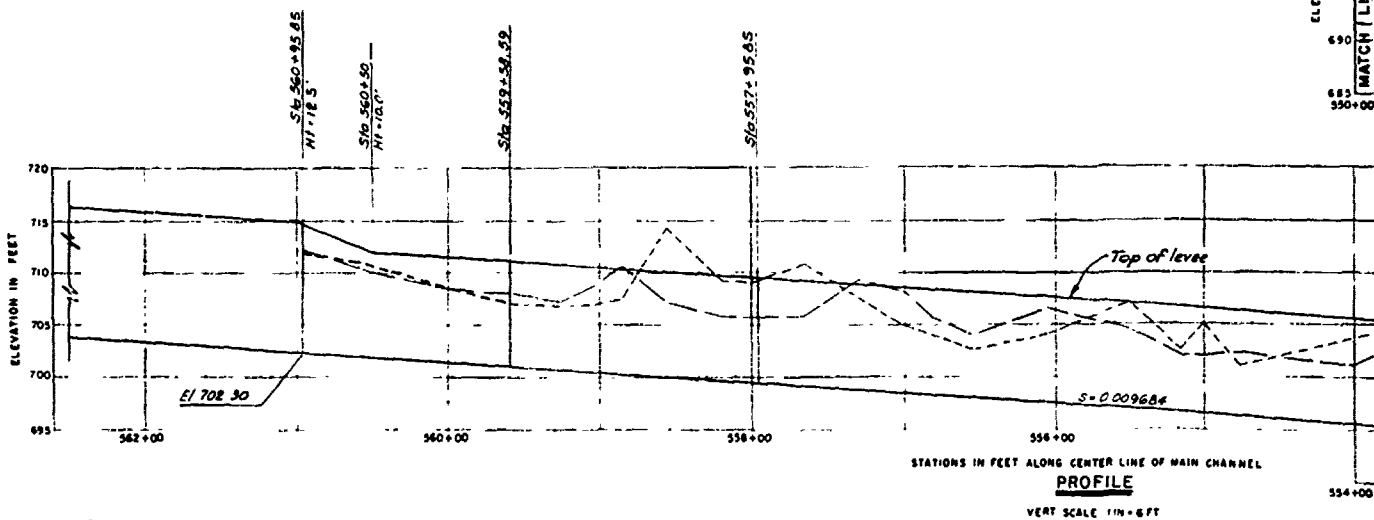


Photo 49. Final design flow conditions; San Antonio channel 10,300 cfs, Chino Creek channel 6,700 cfs



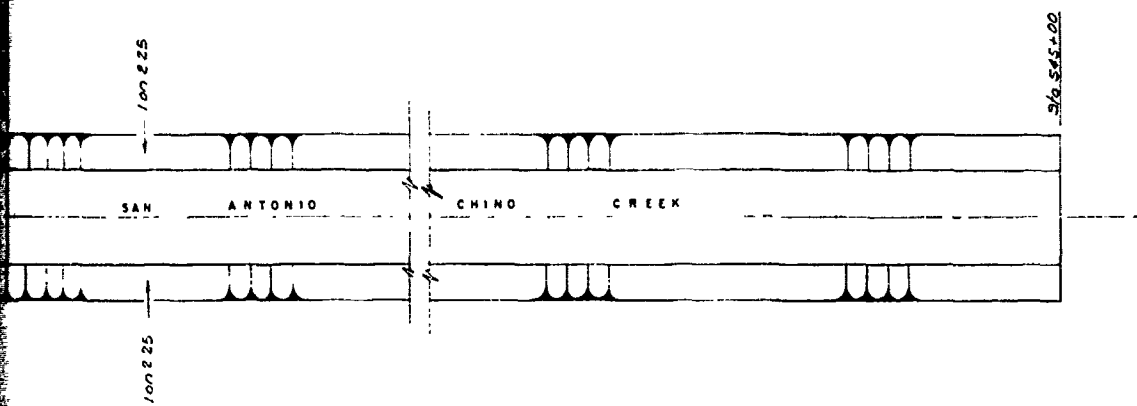
SCALE 1" = 100 FEET

ELEVATION IN FEET
 710
 705
 700
 695
 690
 685
 680+00

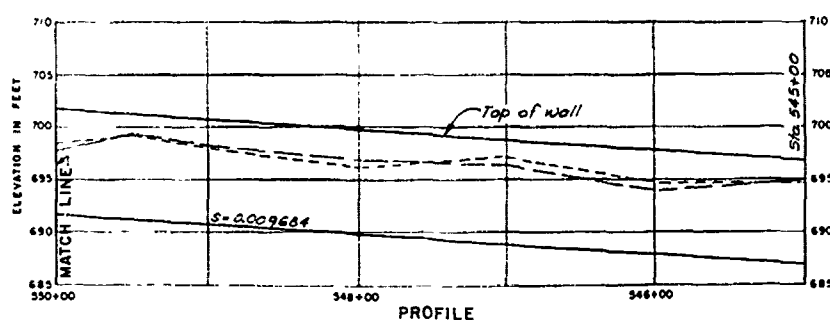


LEGEND

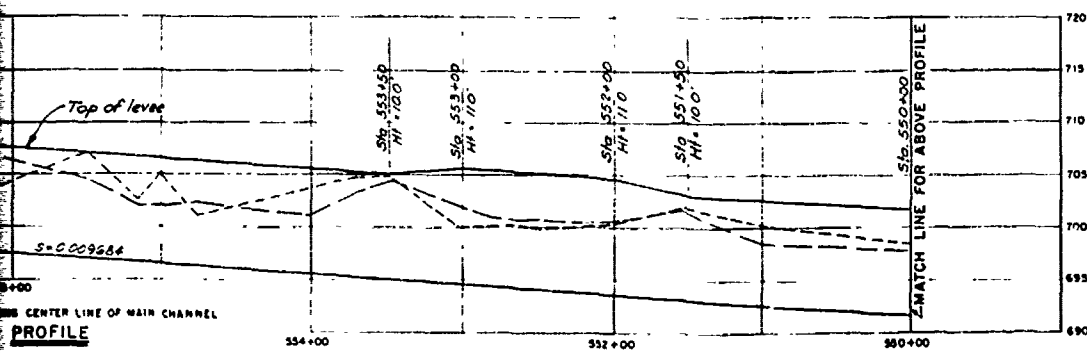
LEFT WALL WATER SURFACE - - - - -
 RIGHT WALL WATER SURFACE - - - - -



PLAN
0 50 100 FEET



PROFILE



CENTER LINE OF MAIN CHANNEL

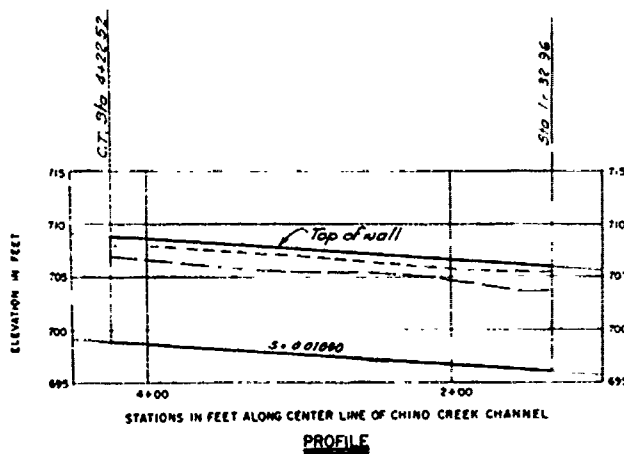
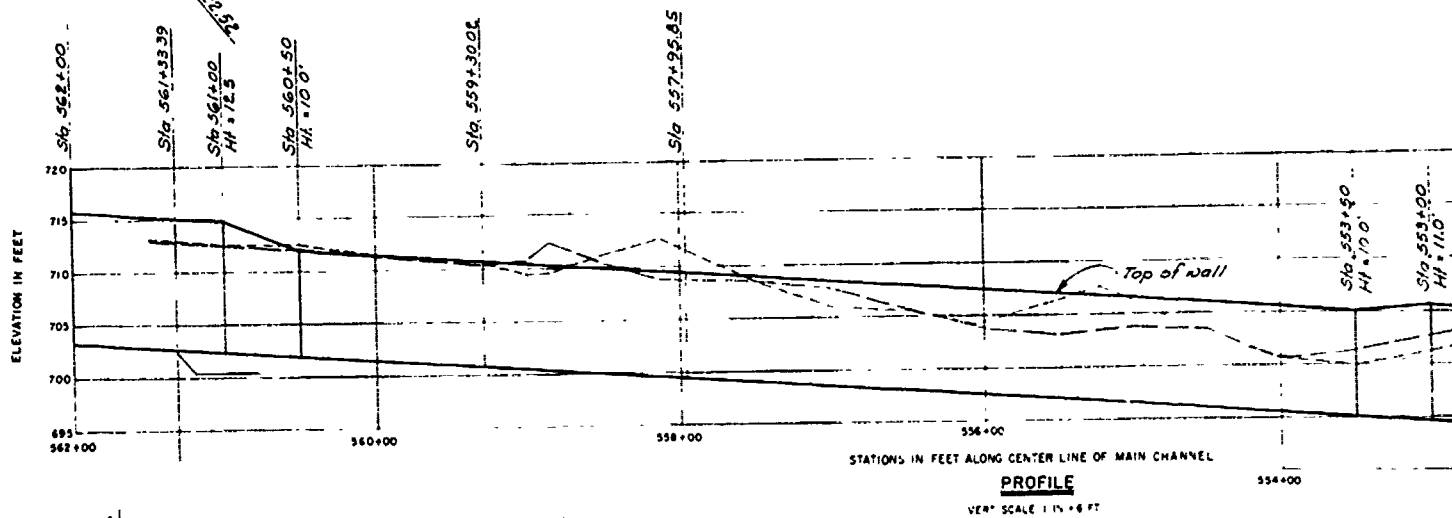
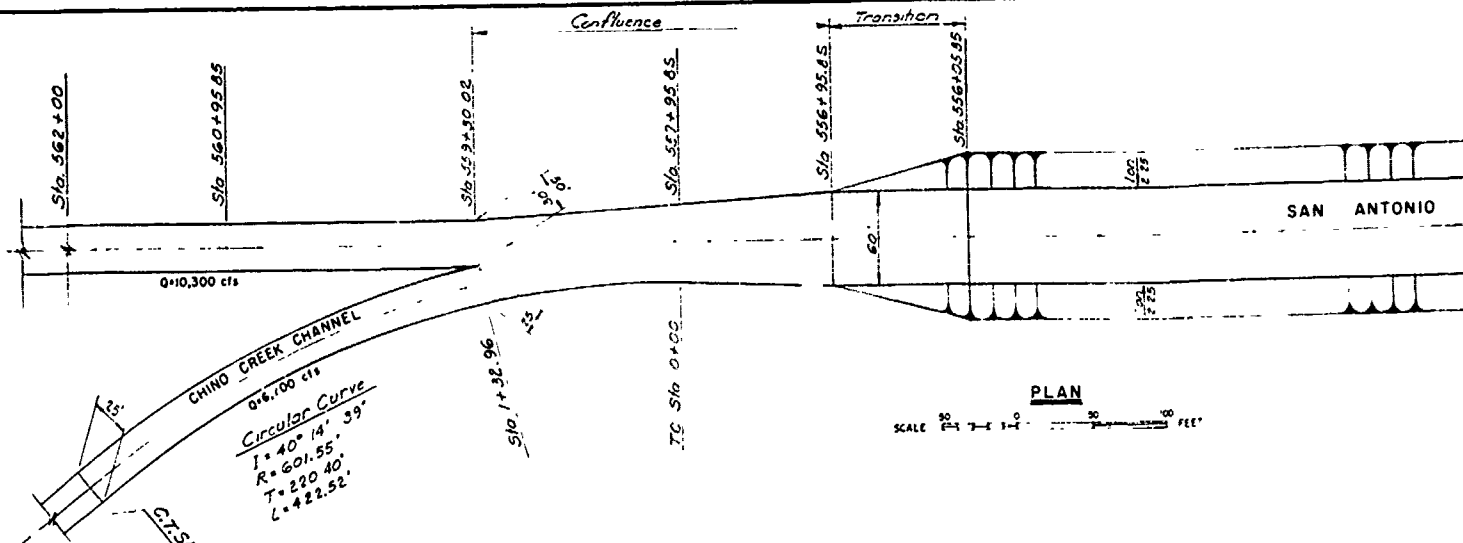
PROFILE

SCALE: 1" = 60'

LEGEND

LEFT WALL WATER SURFACE -----
RIGHT WALL WATER SURFACE -----

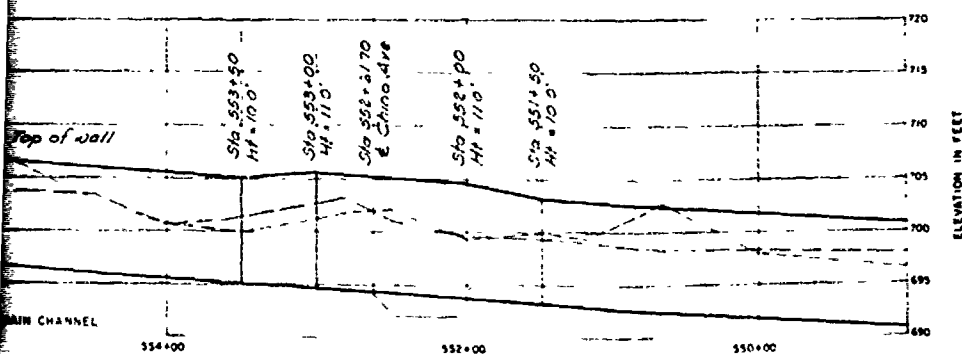
MODEL LAYOUT
AND
WATER-SURFACE PROFILES
ORIGINAL DESIGN
TOTAL DISCHARGE 17,000 cfs



LEG
 LEFT WALL WATER SH
 RIGHT WALL WATER SH

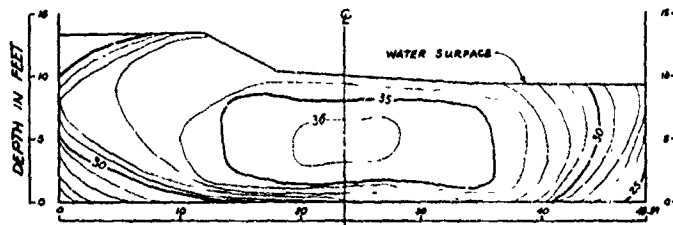
SAN ANTONIO CHANNEL

Sta 549+00

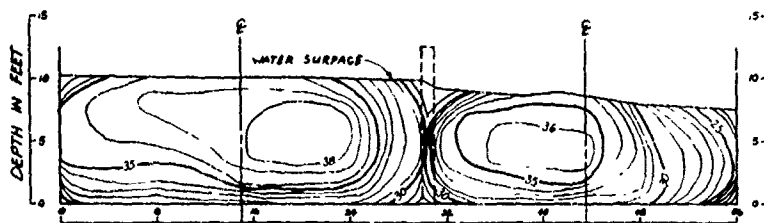
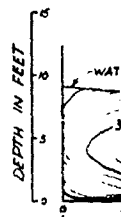


LEGEND
 LEFT WALL WATER SURFACE
 RIGHT WALL WATER SURFACE

MODEL LAYOUT
 AND
 WATER-SURFACE PROFILES
 ALTERNATE DESIGN
 TOTAL DISCHARGE 17,000cfs

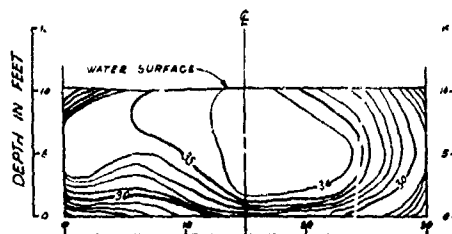
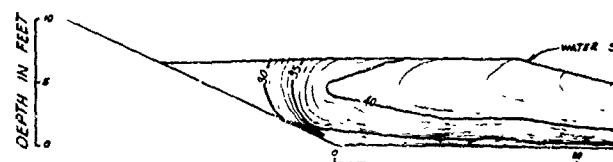
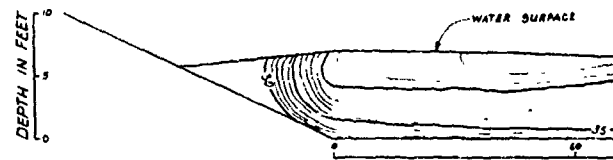


STA 557+95.85



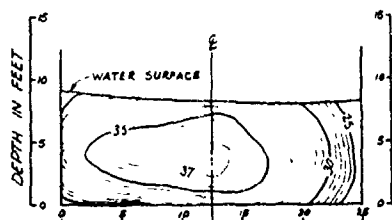
STA 559+30.02

STA 1+32.96

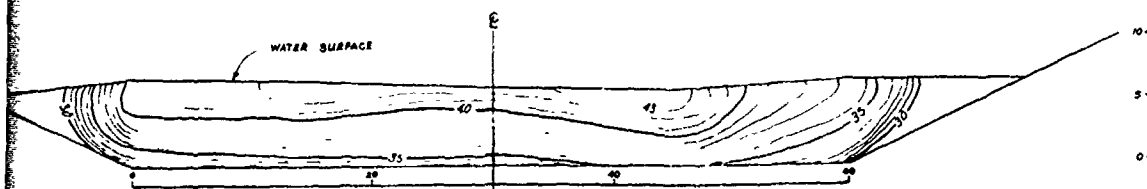


TS STA 560+95.85

NOTE
ALL SECTIONS SHOWN LOOKING DOWNSTREAM
VELOCITIES ARE IN FEET PER SECOND.
HORIZONTAL DISTANCE IN FEET FROM LEFT WALL



STA 2+50



STA 550+00

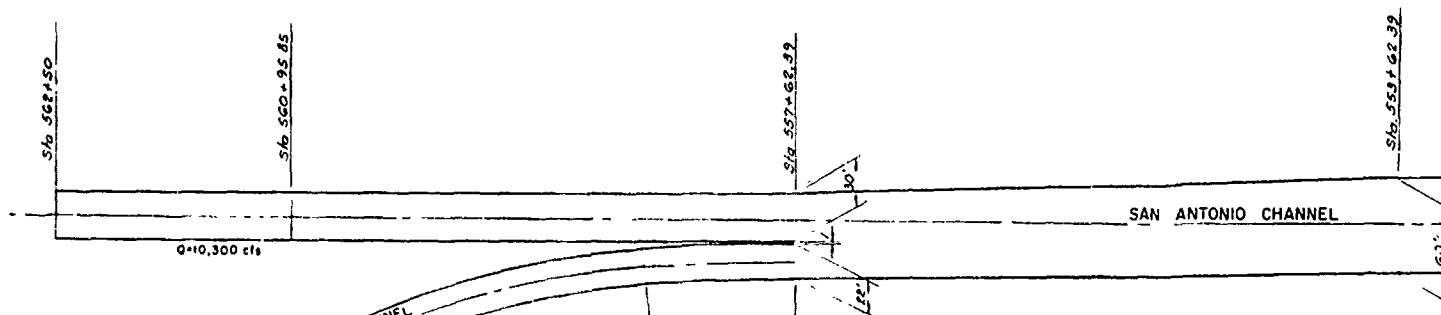


STA 554+50

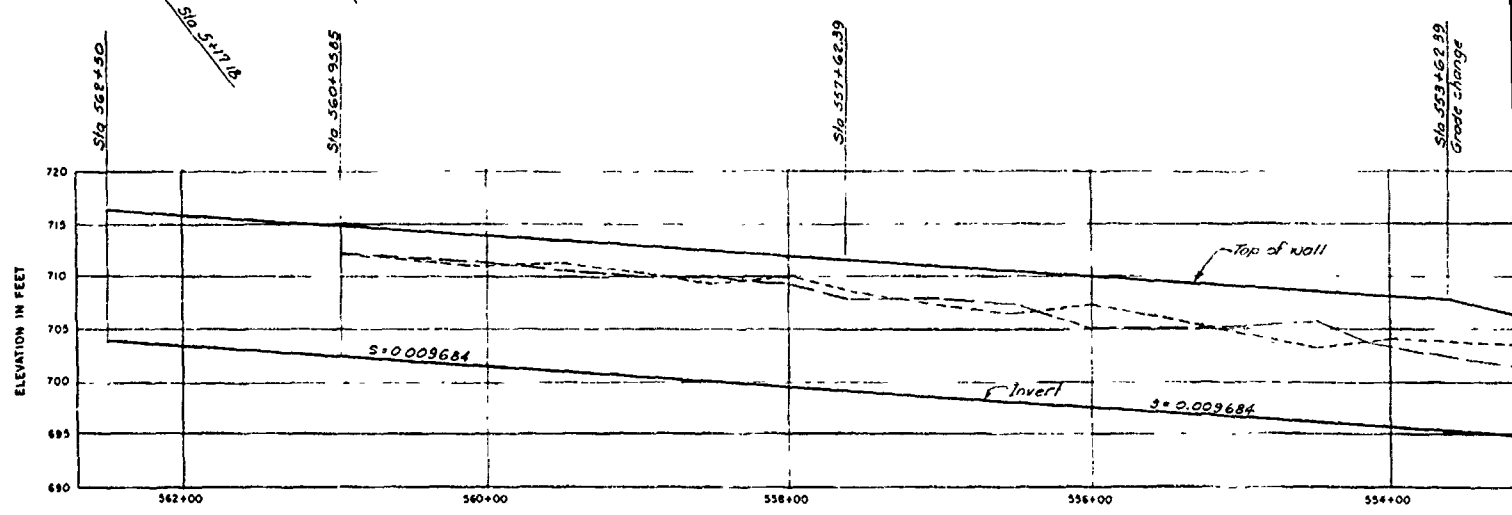
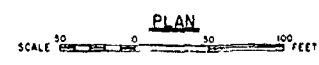
NOTE

ALL SECTIONS SHOWN LOOKING DOWNSTREAM
VELOCITIES ARE IN FEET PER SECOND
HORIZONTAL DISTANCE IN FEET FROM LEFT WALL

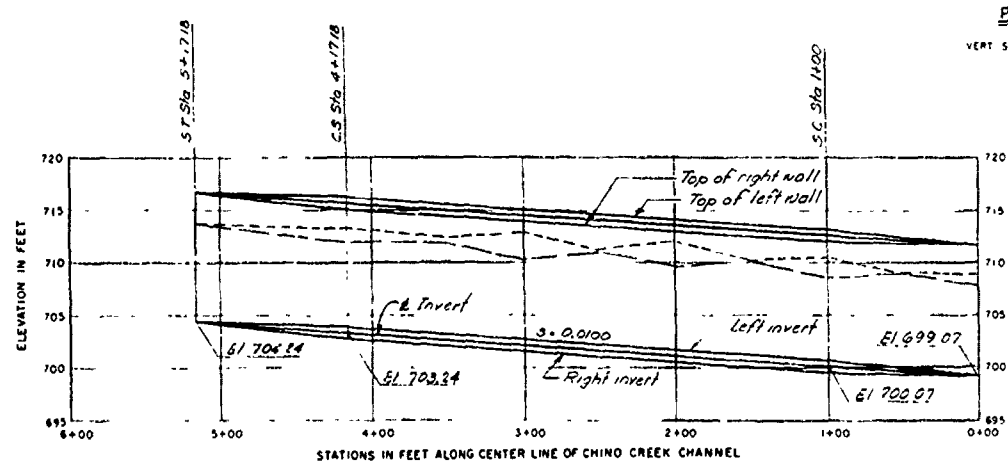
VELOCITY DISTRIBUTION
ALTERNATIVE DESIGN
TOTAL DISCHARGE 17,000 cfs
FLOW COMBINATION: SAN ANTONIO CHANNEL 10,300 cfs
CHINO CREEK 6,700 cfs



Curve Data
 Circular Curve - Modified Spiral No 280
 $\Delta = 30^\circ - 17' - 19''$ $\Delta S = 04^\circ 58' - 40''$
 $R = 600'$ $T_S = 267.93'$
 $T = 162.39'$ $L_S = 100'$
 $L = 317.18'$ $I = 40^\circ 14' 39''$

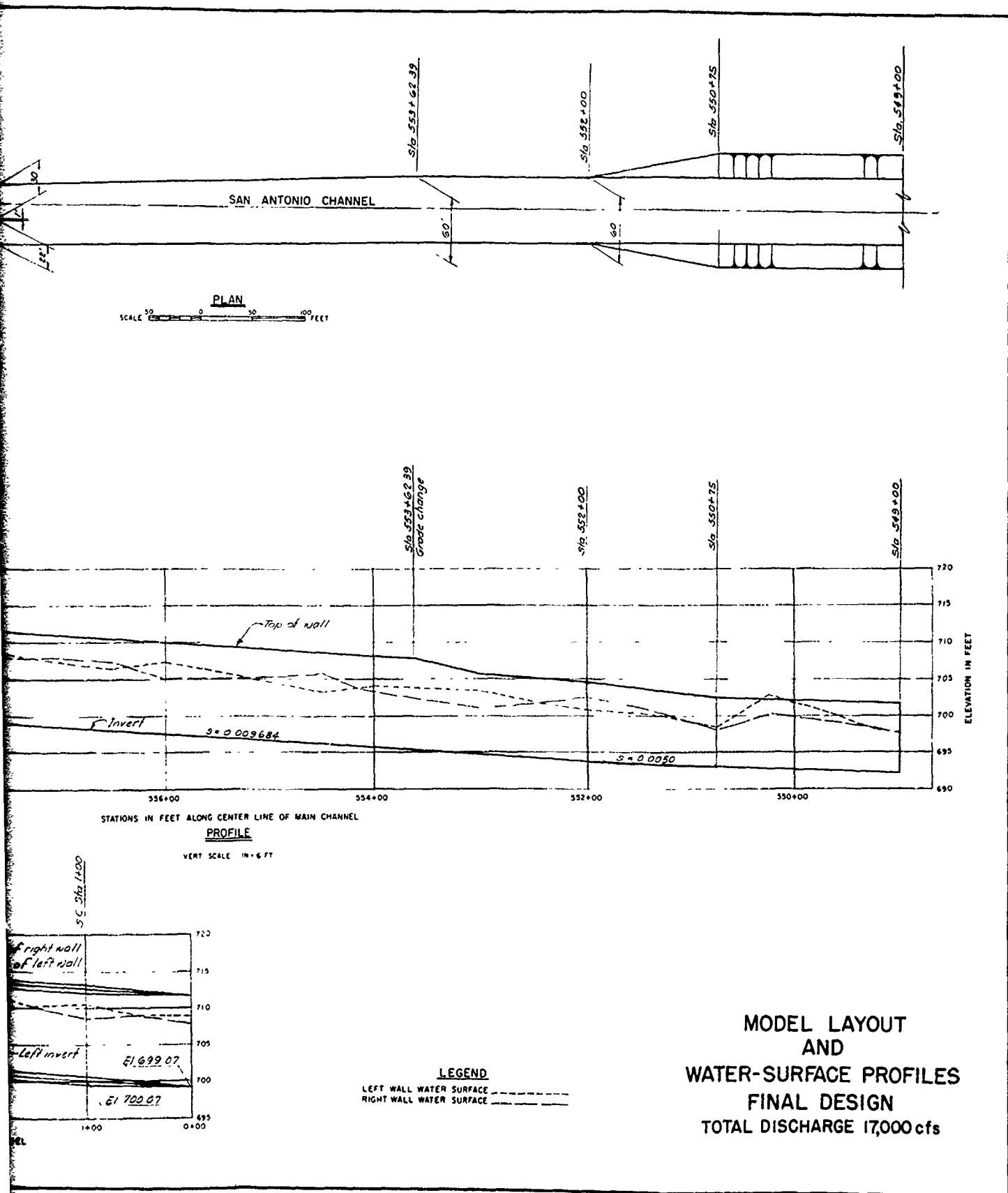


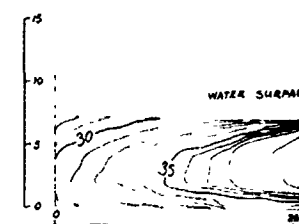
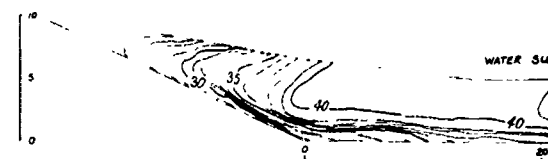
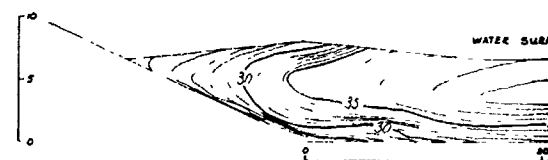
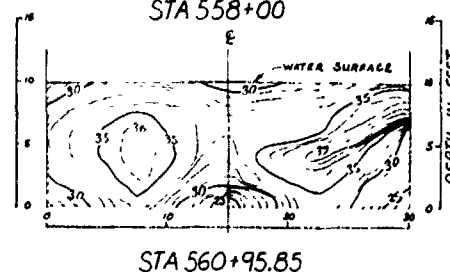
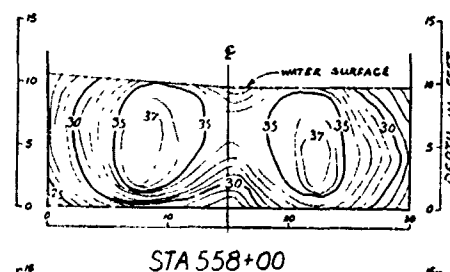
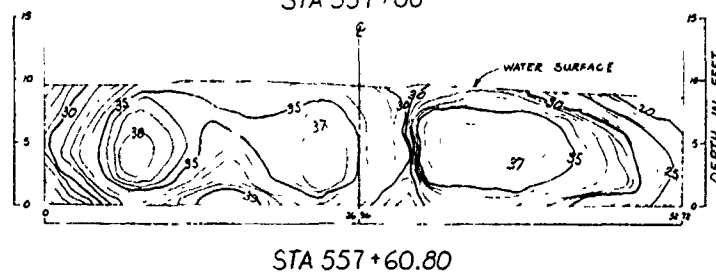
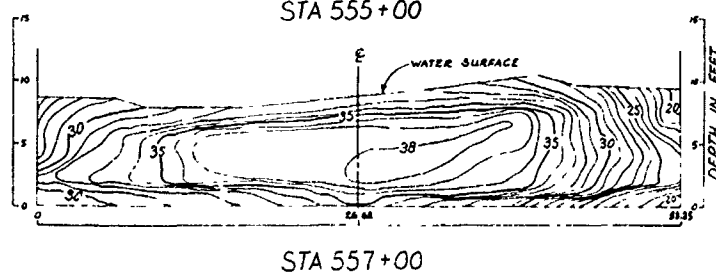
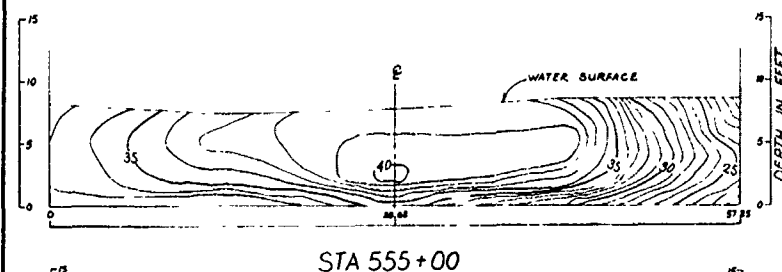
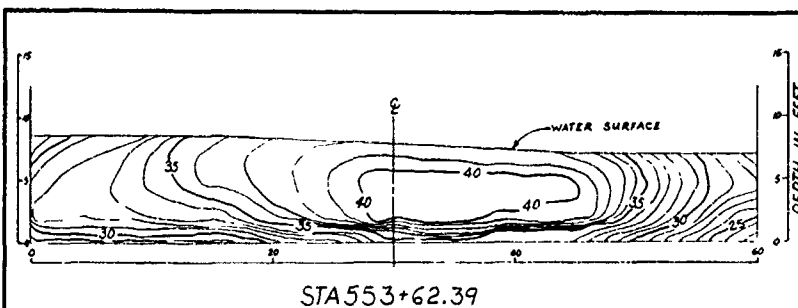
STATIONS IN FEET ALONG CENTER LINE OF MAIN CHANNEL
PROFILE
 VERT SCALE 1 IN = 6 FT



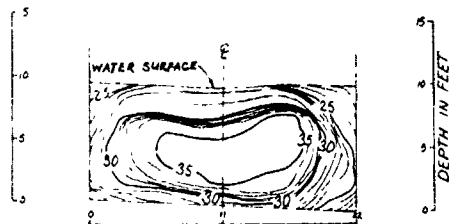
STATIONS IN FEET ALONG CENTER LINE OF CHINO CREEK CHANNEL
PROFILE

LEG:
 LEFT WALL WATER SUR
 RIGHT WALL WATER SUR

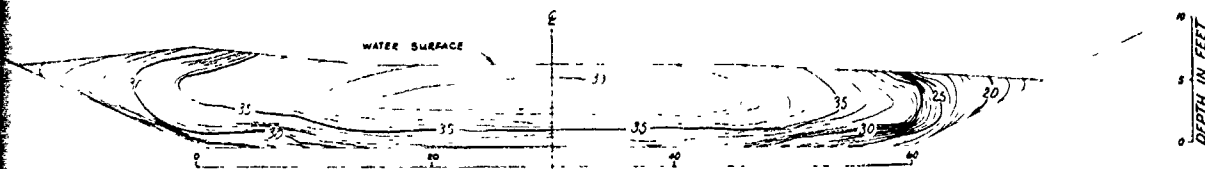




NOTE
ALL SECTIONS SHOWN LOOKING
VELOCITIES ARE IN FEET PER
HORIZONTAL DISTANCE IN FEET



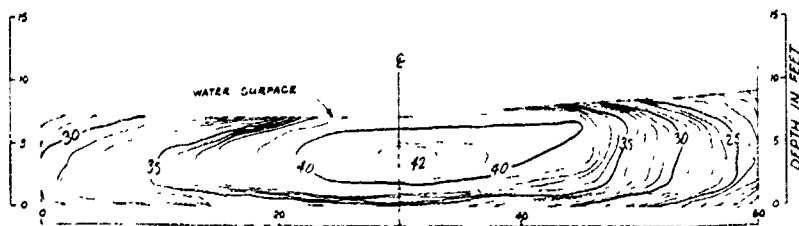
STA 3+50



STA 546+25



STA 550+25



STA 552+00

NOTE

ALL SECTIONS SHOWN LOOKING DOWNSTREAM
VELOCITIES ARE IN FEET PER SECOND
HORIZONTAL DISTANCE IN FEET FROM LEFT WALL

VELOCITY DISTRIBUTION

FINAL DESIGN

TOTAL DISCHARGE 17,000 cfs

FLOW COMBINATION SAN ANTONIO CHANNEL 10,300 cfs
CHINO CREEK 6,700 cfs

PACOIMA WASH CHANNEL-WILSON MANSFIELD CHANNEL

The Model

60. The reach of Pacoima Wash channel, constructed to a 1:24 scale, extended from sta 295+00 to sta 275+00, a distance of 2000 ft. In this reach, Pacoima Wash channel is a trapezoidal concrete channel with a base width of 10 ft and 1V-on-2H side slopes. The Wilson Mansfield channel reach extended from the confluence at Pacoima Wash channel to sta 15+00. The basic design of the Wilson Mansfield channel consists of a rectangular concrete channel with a base width of 22 ft. This channel intersects the right levee of Pacoima Wash channel at an angle of 15 degrees (Photo 50).

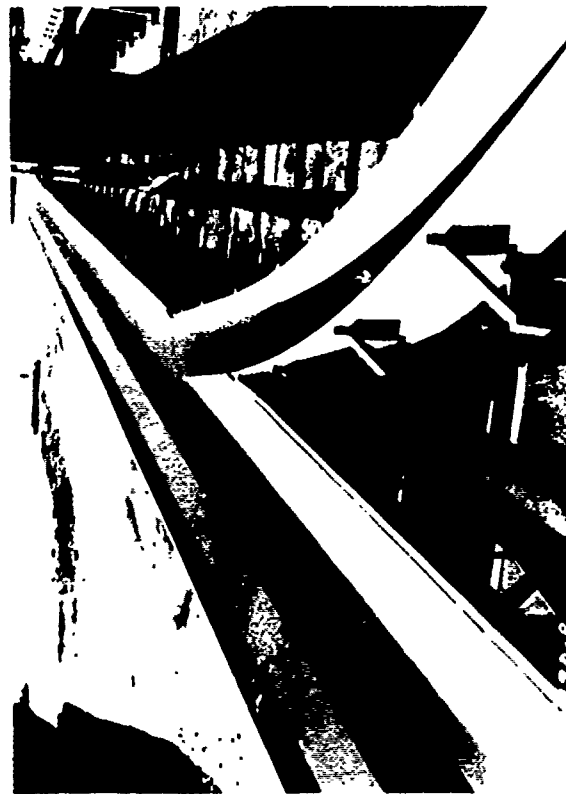
Final Design

61. The first observations and measurements were made with a flow combination of 11,000 cfs (standard project flood) in Pacoima Wash channel and 800 cfs in the Wilson Mansfield channel, producing a combined discharge of 11,800 cfs in Pacoima Wash channel downstream from the confluence. When all test data had been obtained with this combination, observations and measurements were made with a flow combination of 4500 cfs in Pacoima Wash channel and 7500 cfs (standard project flood) in Wilson Mansfield channel.

62. With the 11,000 and 800 cfs combination, the water-surface differential between the two channels was approximately 2 ft. The greater discharge of Pacoima Wash channel against the much lesser flow of Wilson Mansfield channel produced considerable impact and ride-up on the left levee just downstream of the junction. Resulting waves in Pacoima Wash channel traversed from wall to wall as the flow continued downstream. The design levee heights did not provide adequate free-board to confine the waves (Photo 51). The water-surface profiles are shown in Plate 35.

63. The design discharge of 7500 cfs in Wilson Mansfield channel

and 4500 cfs in Pacoima Wash channel was considered the most severe that would exist in the prototype. There was little change in the water surface throughout the confluence and in the Pacoima Wash channel downstream; however, the waves with this combination diminished as they progressed downstream. Flow conditions for this combination are shown in Photo 52 and water-surface profiles in Plate 36.



Looking downstream from sta 295+00,
right side of Pacoima Wash



Looking upstream from sta 286+00,
left side of Pacoima Wash

Photo 50. Final design, Pacoima Wash channel-Wilson ...sfeld channel



Looking upstream from sta 286+00



Looking downstream from centerline of
Pacoima Wash, sta 293+00

Photo 51. Final design flow conditions;
Pacoima Wash 11,000 cfs, Wilson Mansfield 800 cfs

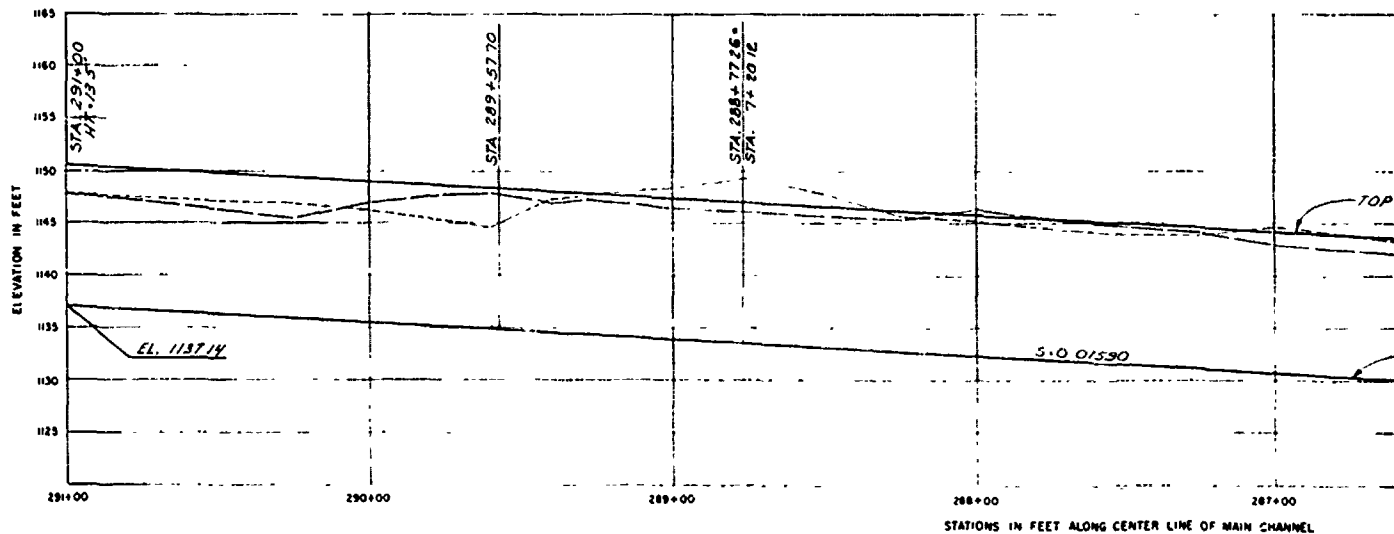
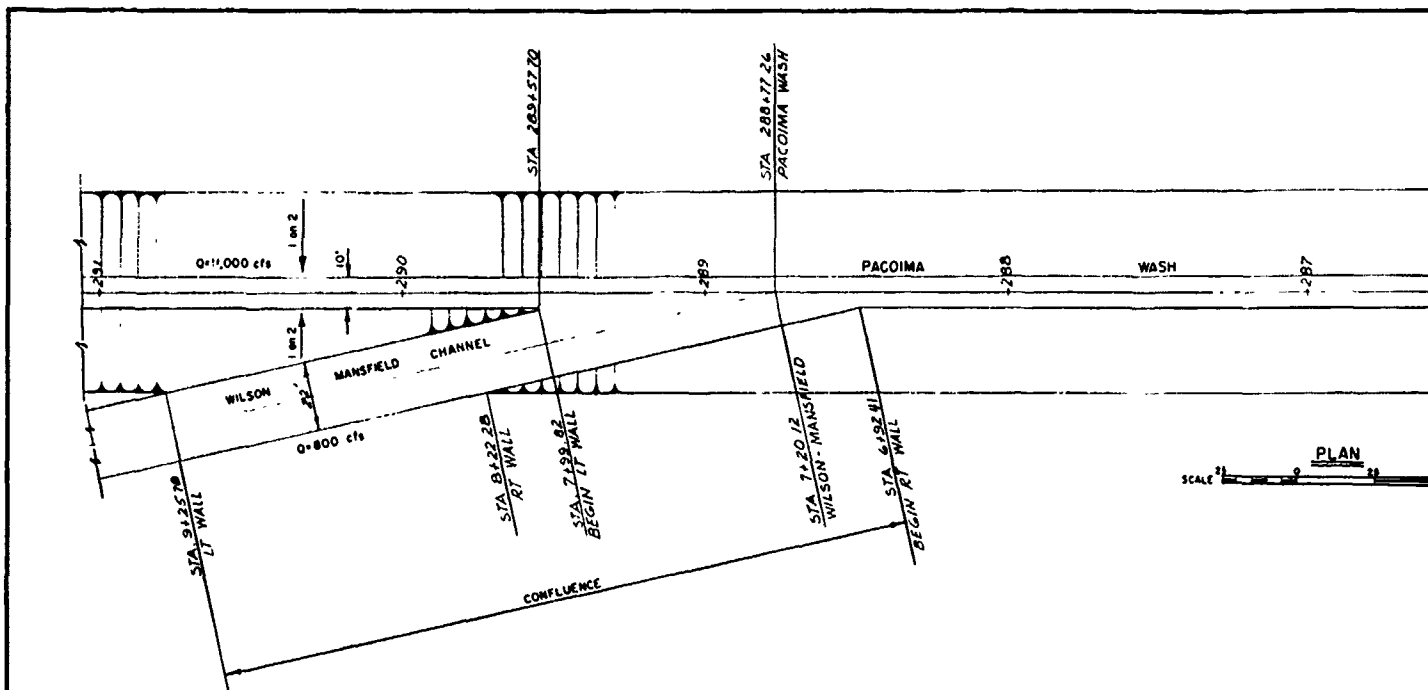


Looking downstream from centerline of
Pacoima Wash, sta 294+00



Looking upstream from sta 285+50

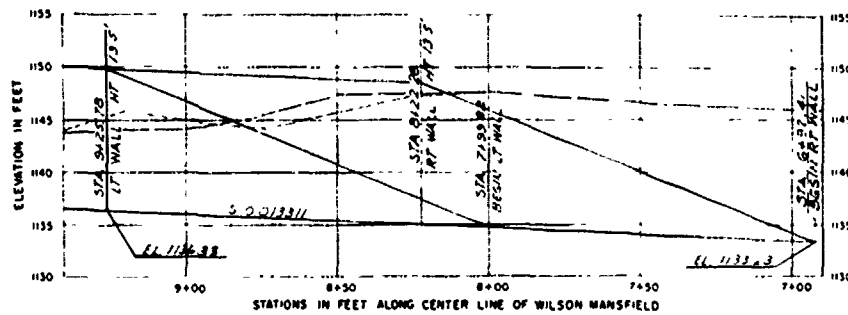
Photo 52. Final design flow conditions;
Pacoima Wash 4500 cfs, Wilson Mansfield 7500 cfs



STATIONS IN FEET ALONG CENTER LINE OF MAIN CHANNEL

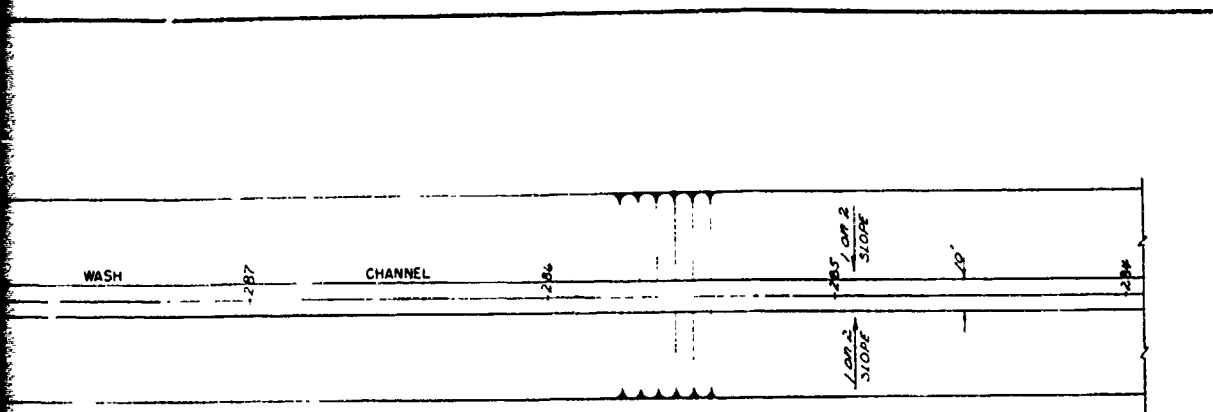
PROFILE

VERT SCALE 1" = 6 FT

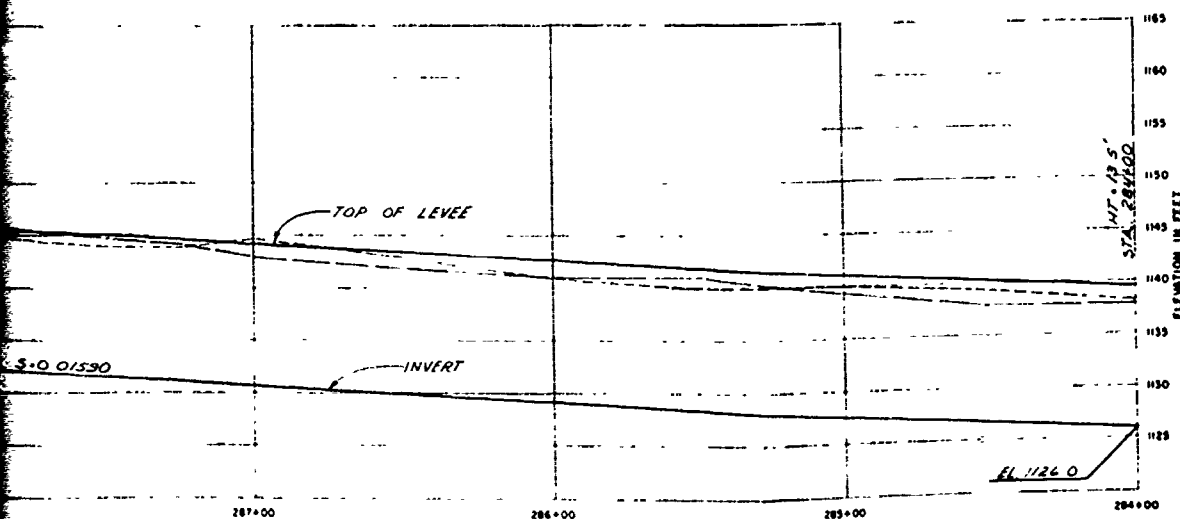


PROFILE

LEFT
RIGHT



PLAN
SCALE 1" = 20 FEET



FEET ALONG CENTER LINE OF MAIN CHANNEL

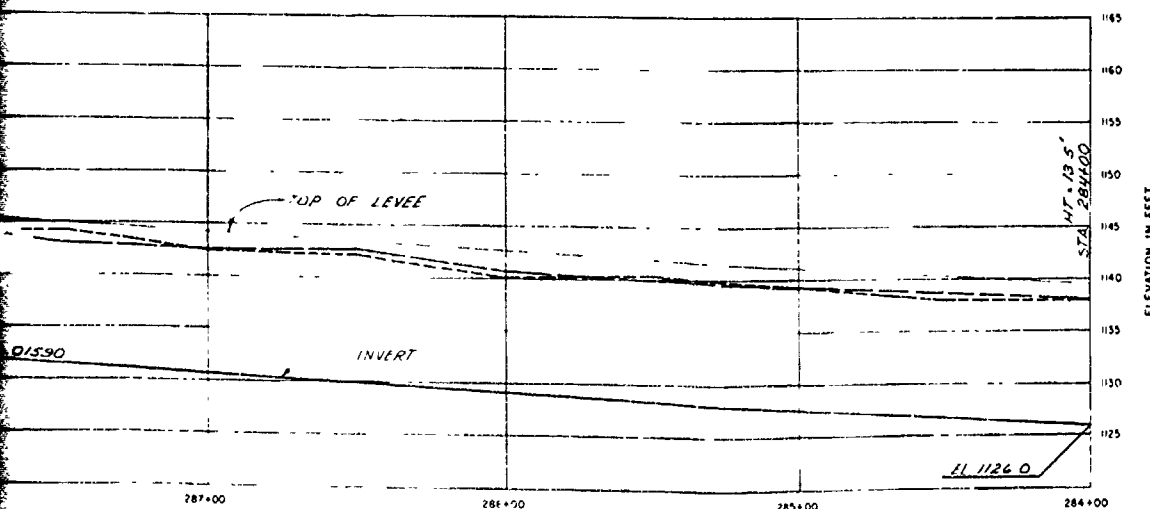
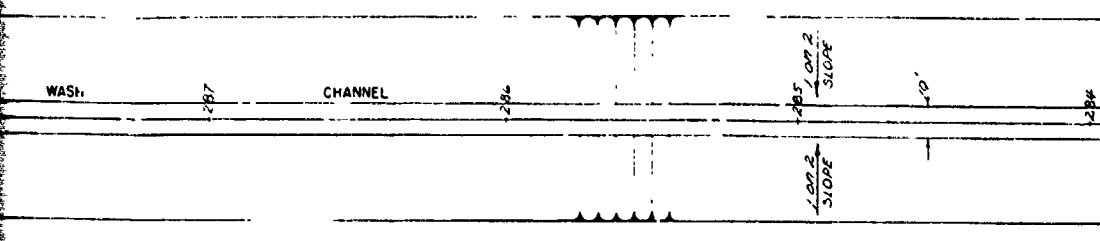
PROFILE

VERT SCALE 1" = 6 FT

LEGEND
LEFT WALL WATER SURFACE
RIGHT WALL WATER SURFACE

MODEL LAYOUT
AND
WATER-SURFACE PROFILES
FINAL DESIGN
TOTAL DISCHARGE 11,800 cfs

PLAN
SCALE 1" = 20 FEET



ALONG CENTER LINE OF MAIN CHANNEL
PROFILE
VERT SCALE 1" = 6 FT

LEGEND
LEFT WALL WATER SURFACE -----
RIGHT WALL WATER SURFACE -----

MODEL LAYOUT
AND
WATER-SURFACE PROFILES
FINAL DESIGN
TOTAL DISCHARGE 12,000cfs

TUJUNGA WASH CHANNEL-PACOIMA WASH CHANNEL

The Model

64. In the original design, the confluence structure was 442.65 ft long (sta 348+25.93 to 352+68.58). Pacoima Wash channel was a 50-ft-wide rectangular section, including a 200-ft spiral transition with a superelevated invert and 35.82 ft of straight channel. The right wall of the confluence structure was then aligned along a circular curve with a central angle of 12 degrees and a radius of 2103.27 ft. The extended centerline of Pacoima Wash channel is offset 10 ft from the centerline of Tujunga Wash channel, at sta 348+25.93 or sta 0+00 along the extended centerline of Pacoima Wash channel (Plate 37).

65. Analyses of the flow conditions at the confluence structure for various combinations of discharges in Pacoima Wash channel and Tujunga Wash channel upstream of the junction showed that the maximum water surface downstream from the junction would result when discharges of 17,000 and 12,000 cfs occurred in Pacoima Wash channel and Tujunga Wash channel, respectively. Tests of the original design with this combination indicated that the confluence and transition downstream from the junction was too short, resulting in the formation of large waves which were reflected from wall to wall for a considerable distance downstream. Measurements were taken in a 1:30-scale model but are not shown in this report because the shortness of the confluence structure represented in the model produced results of doubtful value.

Final Design

66. To correct the more pronounced deficiencies of the original design, a revised confluence structure was constructed as shown in Photo 53. In this design, Pacoima Wash channel was widened to 55 ft, the extension of the centerline intersected the centerline of Tujunga Wash channel at an angle of 15 degrees instead of 12 degrees, and the point of intersection of the walls of the two channels (divider wall)

was moved downstream about 80 ft. The confluence and transition was lengthened to sta 342+79.17 where Tujunga Wash channel has a base width of 70 ft.

67. The standard project flood discharges that were used in the design of Pacoima Wash channel and Tujunga Wash channel upstream from the junction were 17,000 and 22,000 cfs, respectively. The Tujunga Wash channel downstream from the confluence was designed for a capacity of 29,000 cfs. The combinations of flow tested were as follows:

	<u>Discharge, cfs</u>	<u>Discharge, cfs</u>
Tujunga Wash channel	12,000	22,000
Pacoima Wash channel	<u>17,000</u>	<u>7,000</u>
Total	29,000	29,000

68. This design (Photos 54 and 55) produced satisfactory results for the two flow combinations. The formation of waves by the interference of the high-velocity flow from both channels at the confluence structure and for some distance downstream was reduced by the long confluence and transition. Tests on this design disclosed a much improved water surface. Water-surface profiles along the walls were measured and plotted to determine the adequacy of the height of channel walls. The water-surface profiles for the two combinations are shown in Plates 38 and 40 and the velocity distribution cross sections are shown in Plates 39, 41, and 42. To provide additional freeboard to confine the waves, it was recommended that the channel wall heights be increased 1 ft.



Looking upstream at confluence



Closeup of confluence

Photo 53. Final design, Tujunga Wash channel-Pacoima Wash channel



Looking downstream



Looking upstream toward left wall of channel



Looking downstream from right side of
confluence toward left wall

Photo 54. Final design flow conditions; Tujunga Wash channel 12,000 cfs, Pacoima Wash channel 17,000 cfs



Looking downstream

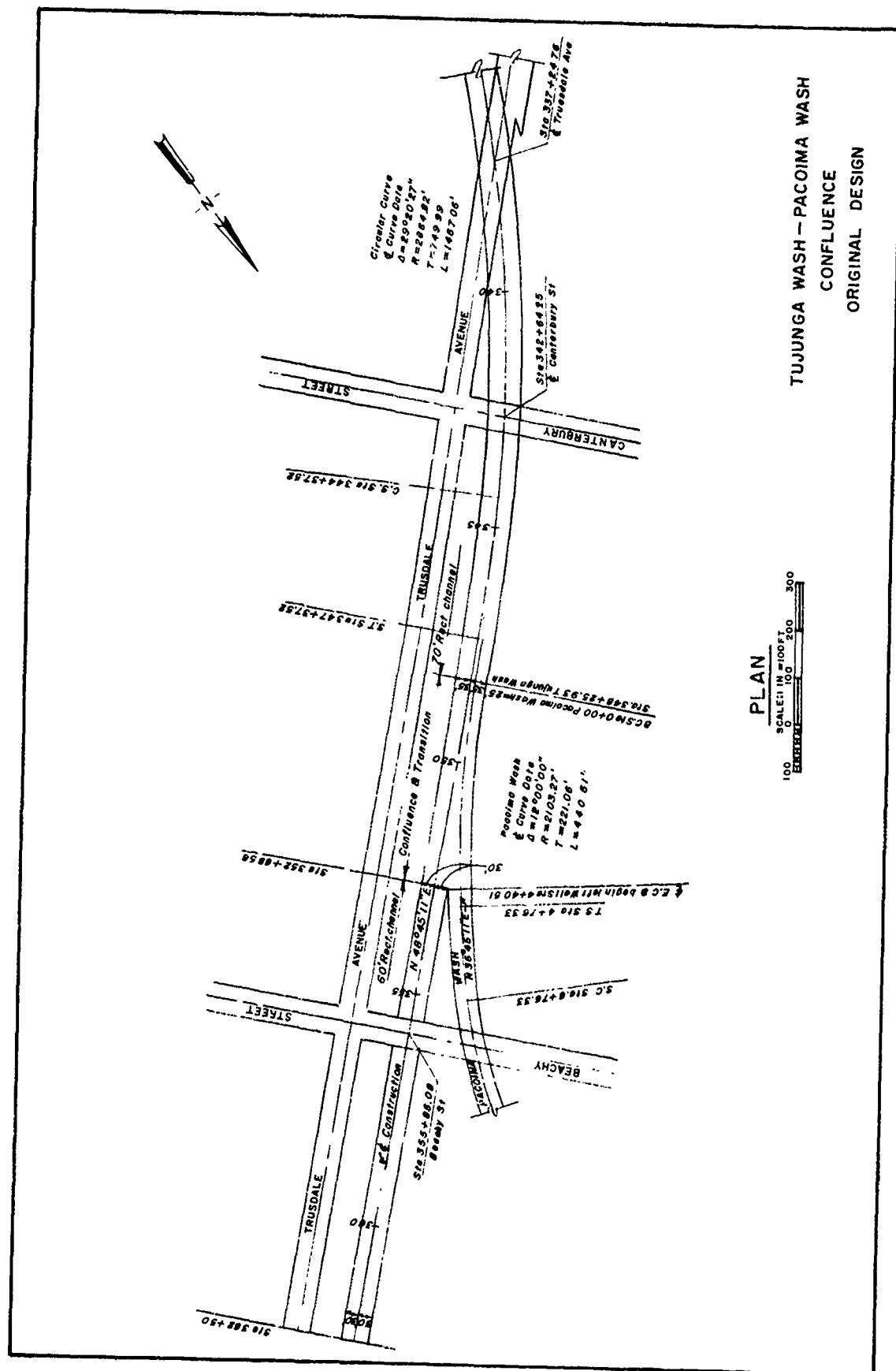


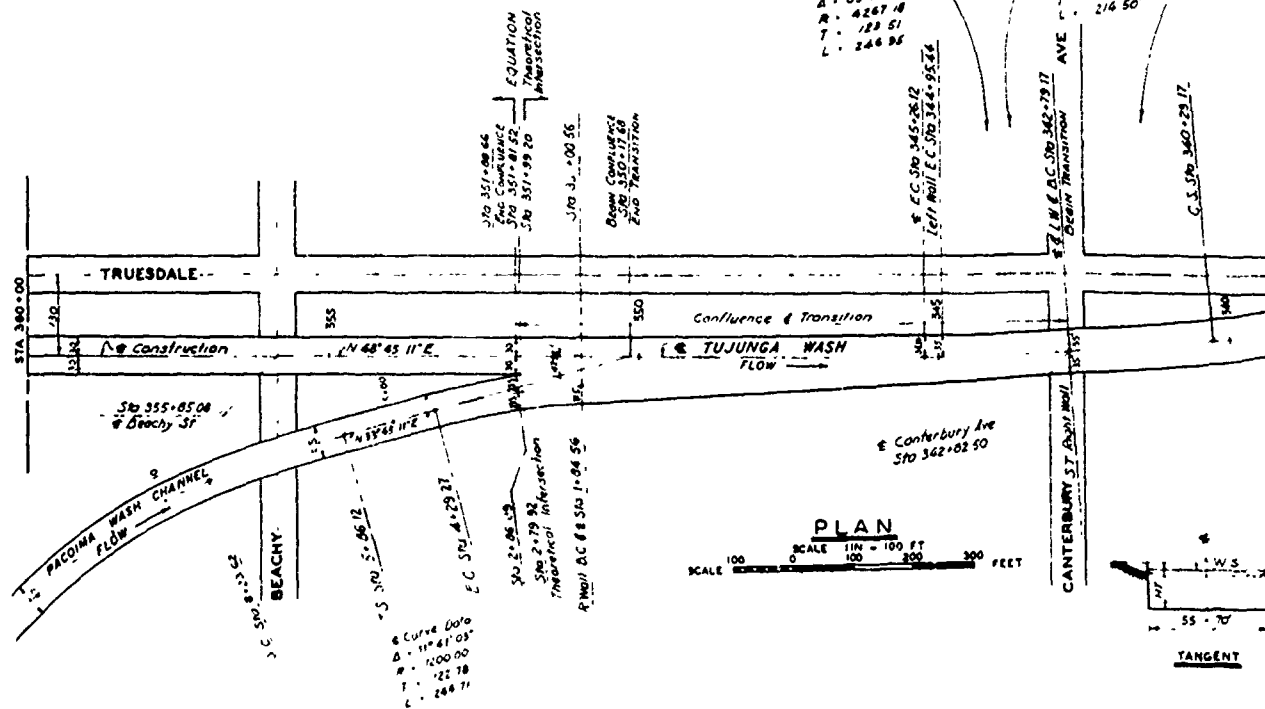
Looking downstream toward right wall

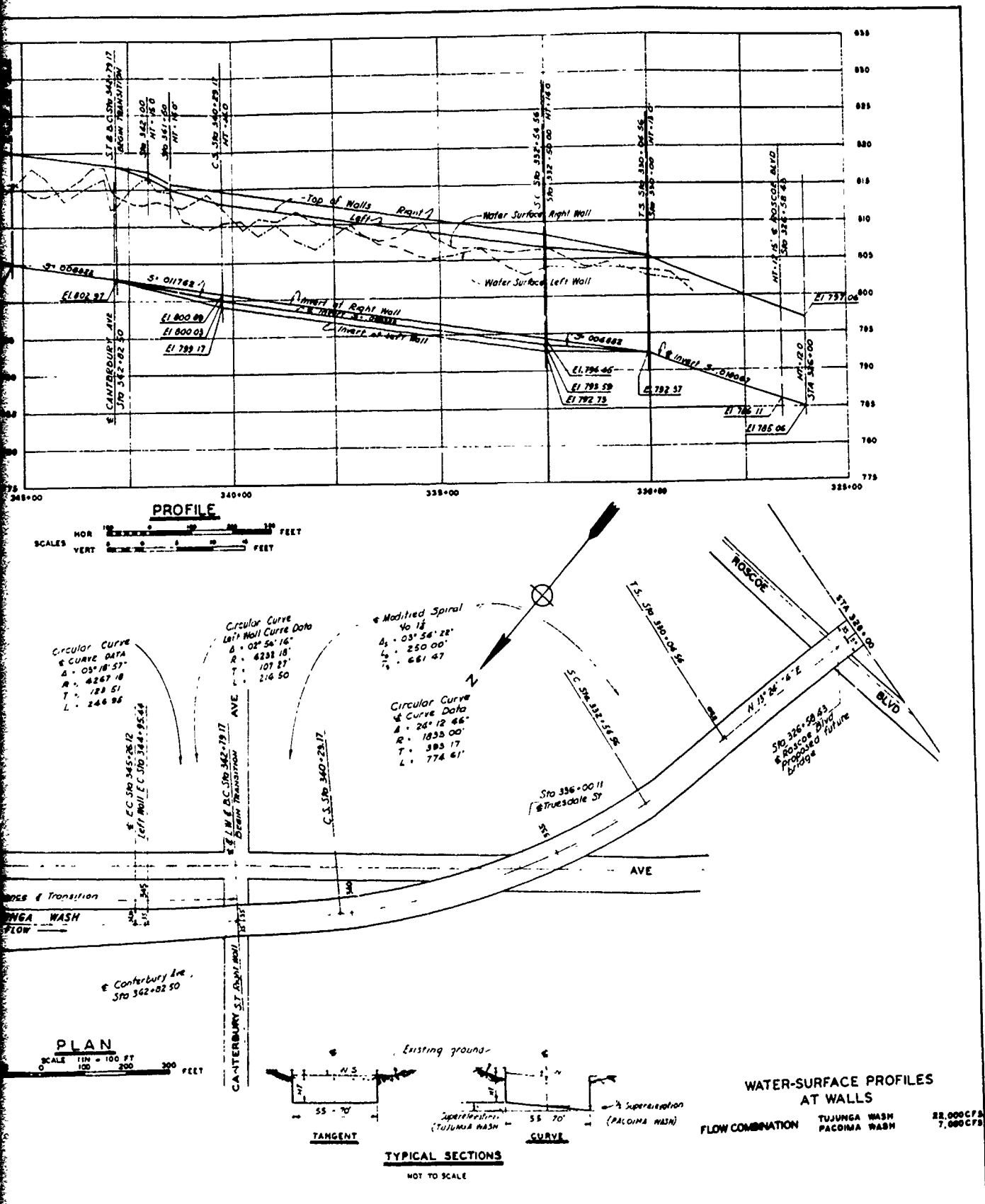


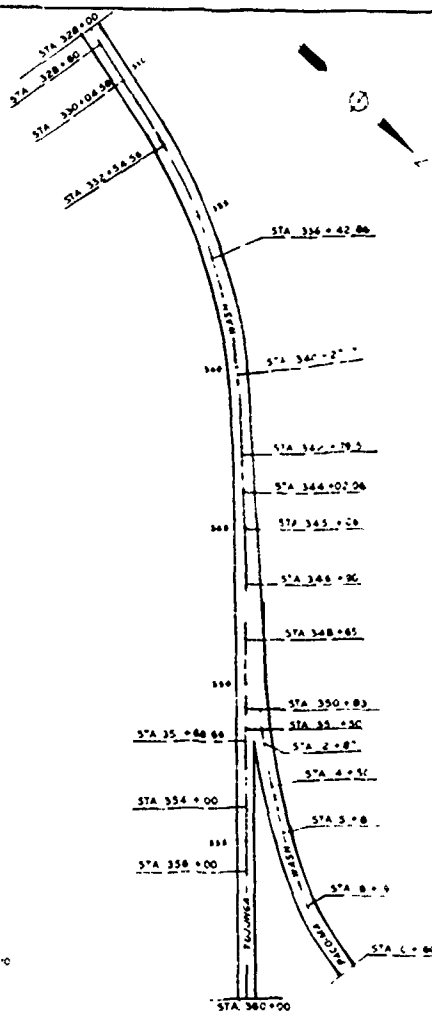
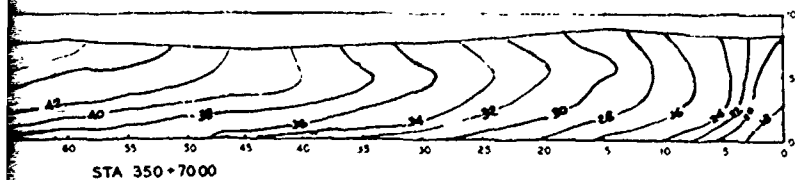
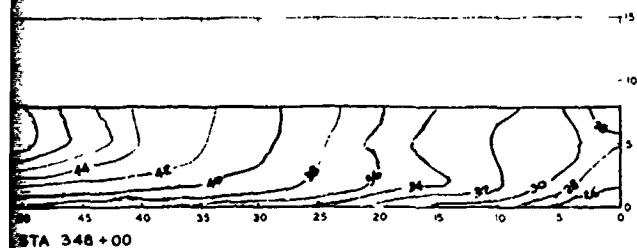
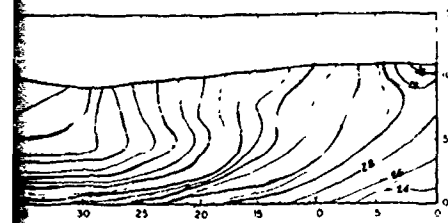
Looking downstream toward left wall

Photo 55. Final design flow conditions;
Tujunga Wash channel 22,000 cfs, Pacoima Wash channel 7,000 cfs





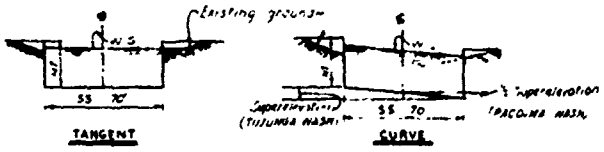
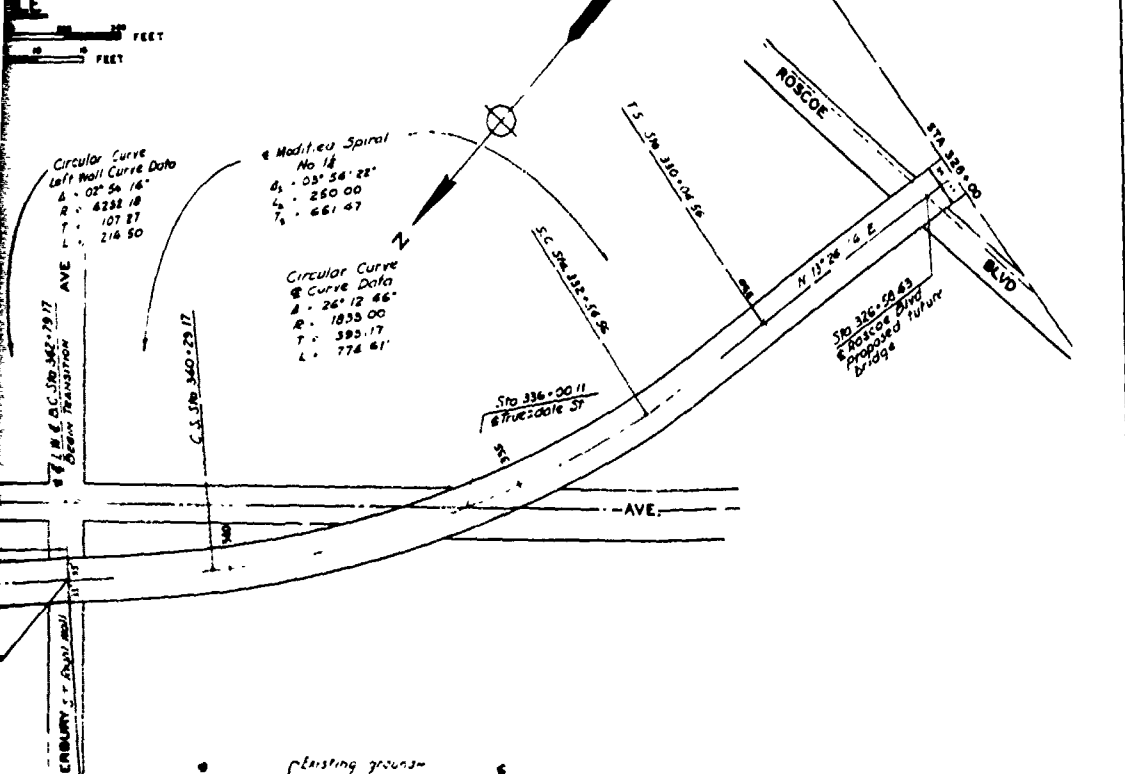
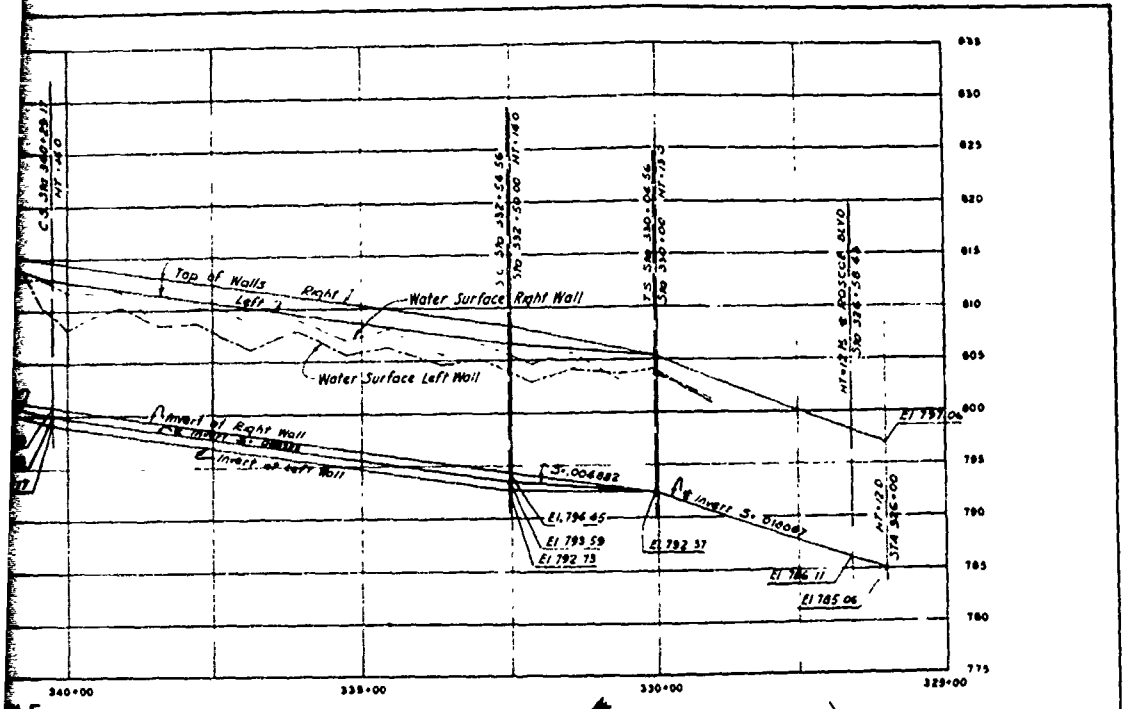




LOCATION OF SECTIONS
SCALE 1" = 100' FEET

NOTE
ALL SECTIONS SHOWN LOOKING DOWNSTREAM
VELOCITIES ARE IN FEET PER SECOND

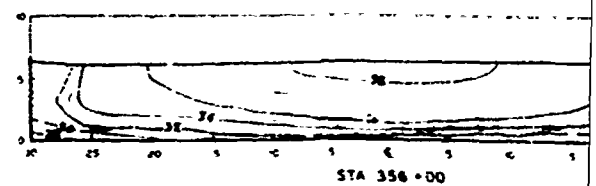
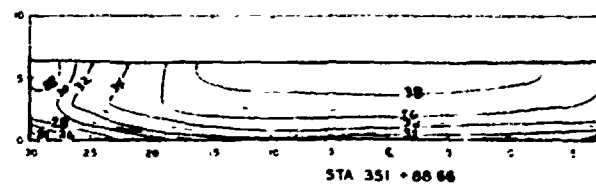
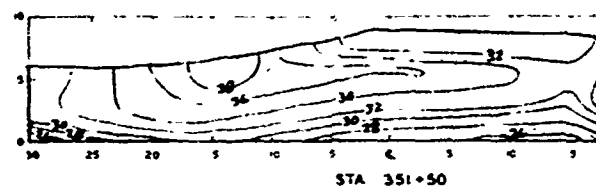
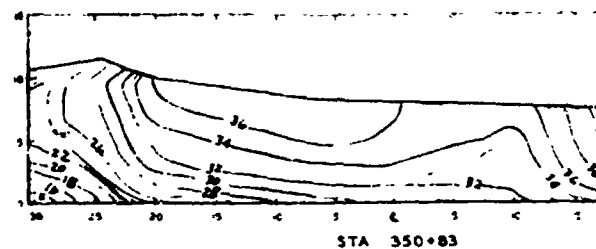
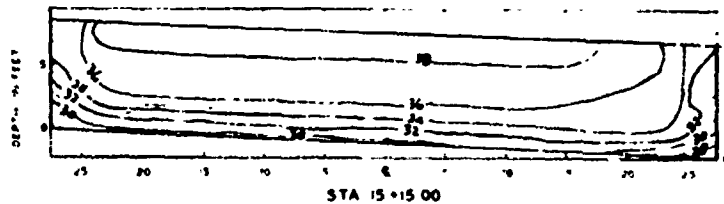
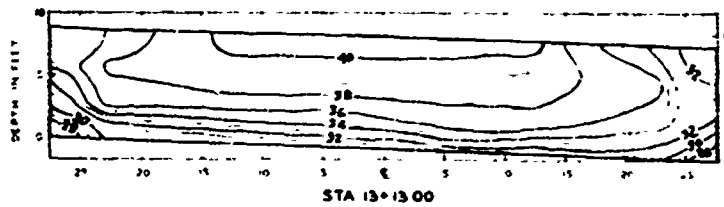
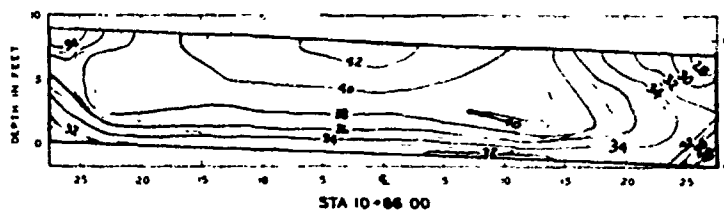
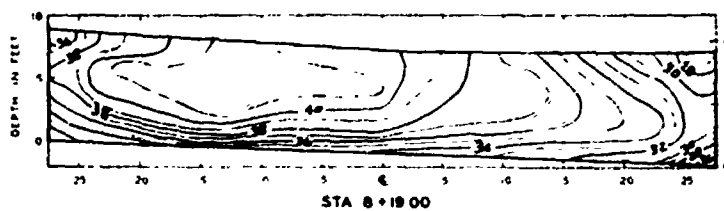
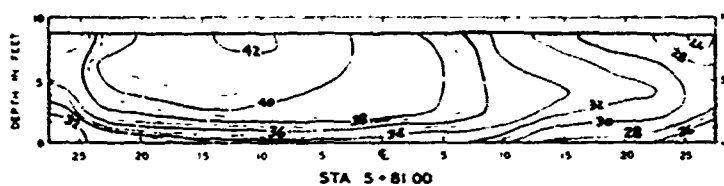
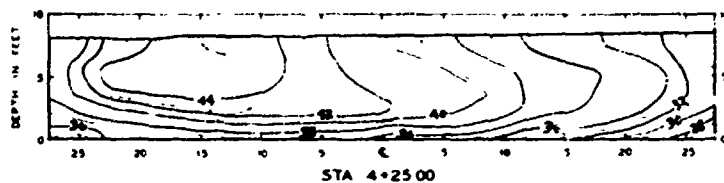
VELOCITY DISTRIBUTIONS
AT THE CONFLUENCE
FLOW COMBINATION PACOMA WASH 7,000 CFS
TUJUNGA WASH 22,000 CFS
SCALE 1" = 100' FEET

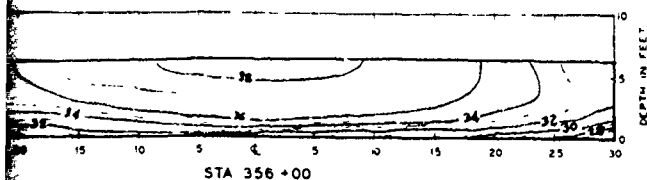
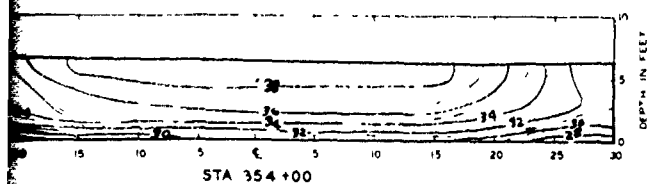
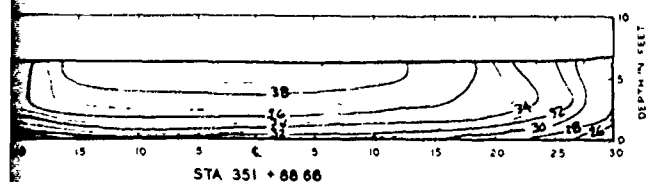
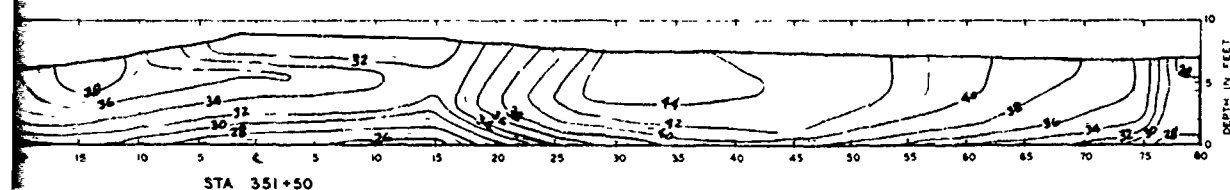
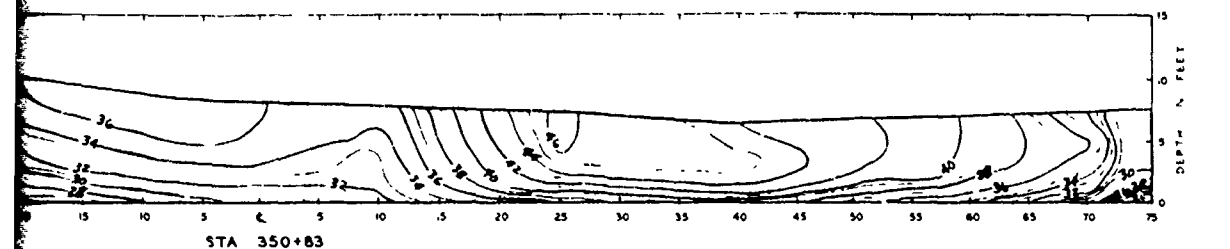


TYPICAL SECTIONS
NOT TO SCALE

WATER-SURFACE PROFILES
AT WALLS

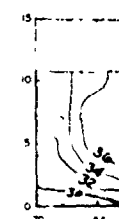
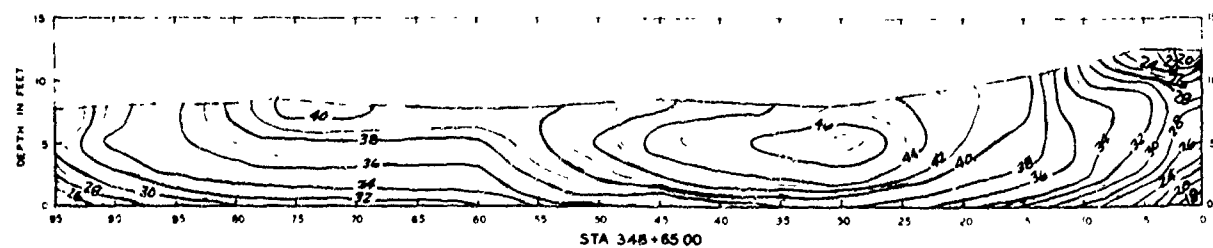
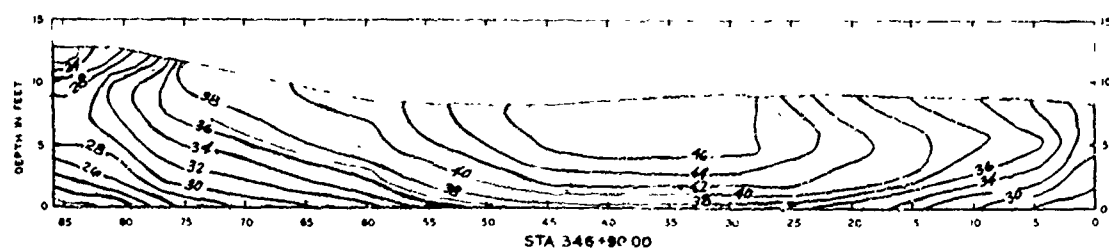
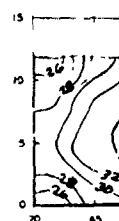
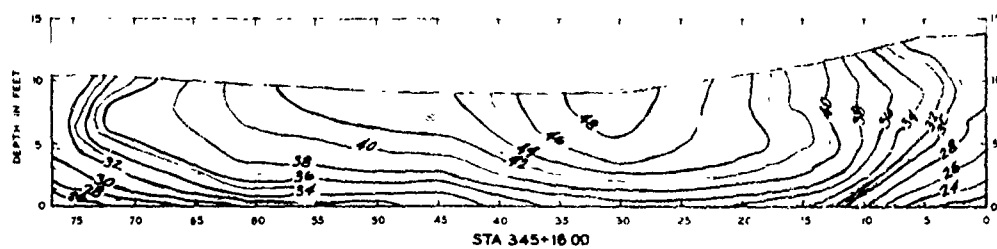
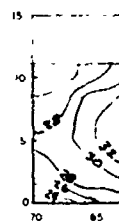
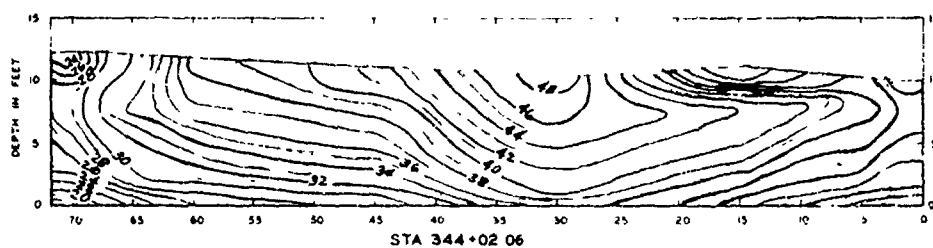
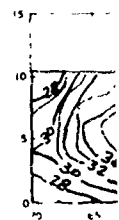
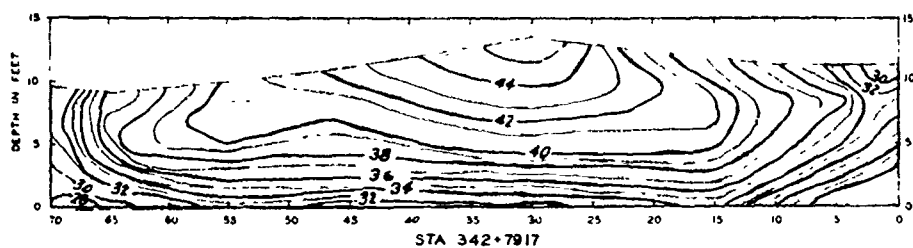
FLOW COMBINATION	TUJUNGA WASH	PACOMA WASH
	12,000 CFS	17,000 CFS

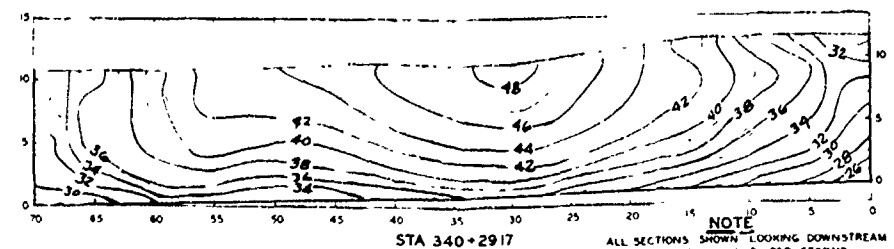
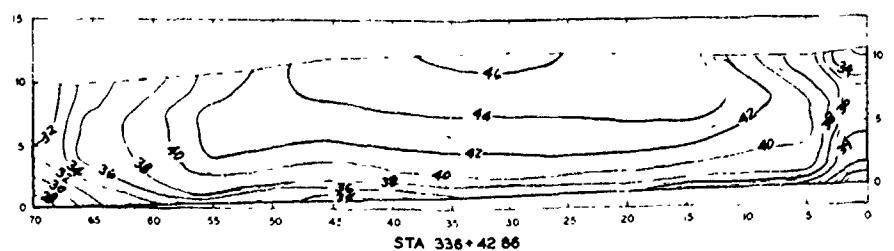
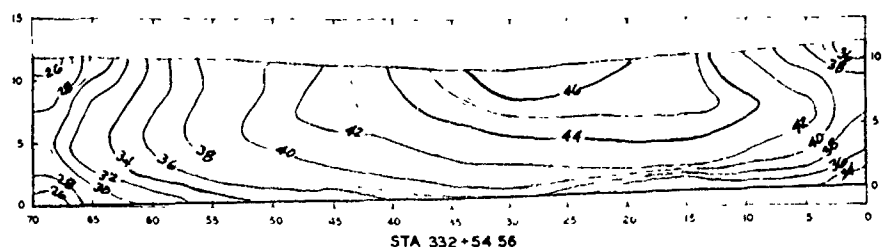
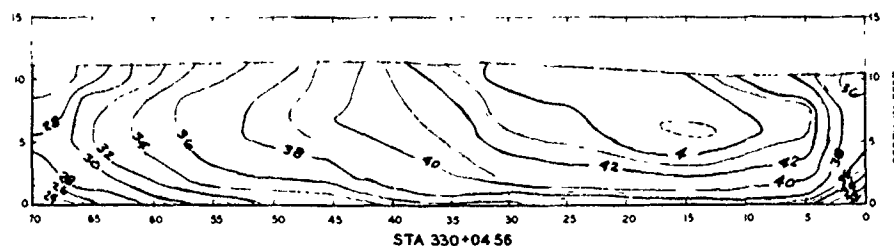
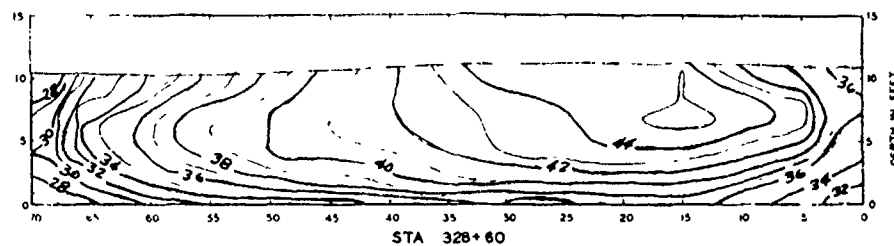




NOTE
ALL SECTIONS SHOWN LOOKING DOWNSTREAM
VELOCITIES ARE IN FEET PER SECOND

**VELOCITY DISTRIBUTIONS
AT THE CONFLUENCE**
FLOW COMBINATION PACOIMA WASH 17,000 C.F.S.
TUJUNGA WASH 12,000 C.F.S.
SCALE 0 5 10 FEET





NOTE

ALL SECTIONS SHOWN LOOKING DOWNSTREAM
VELOCITIES ARE IN FEET PER SECOND

VELOCITIES ARE IN FEET PER SECOND

VELOCITY DISTRIBUTIONS IN TUJUNGA WASH

IN TUJUNGA WASH

FLOW COMBINATION PA. OMA WASH 17,000 CFS
TUJ WGA WASH 12,000 CFS

SCALE $\frac{1}{4}$ IN = 10 FT

PALUNGA WASH	11,000 CF S
TULUNGA WASH	12,000 CF S

SCALE FEET

CONCLUSIONS

69. The results of several model studies on confluences including the eleven studies in this report indicate good flow characteristics with very little wave formation and turbulence at the junction if the following criteria are used as design guides.

- a. Design water-surface elevations in two joining channels should be nearly equal at the upstream end of the confluence.
- b. The angle of channel intersection should be preferably zero but no greater than 12 degrees.
- c. Favorable flow conditions can be achieved with proper expansion in width of main channel downstream of the junction.
- d. Flow depth at the junction should not exceed 85 to 90 percent of critical depth (Froude number should be greater than 1.20) to maintain stable rapid flow through the junction.

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